DEPARTMENT OF THE INTERIOR

REPORT

OF THE

CHIEF ASTRONOMER

BEING PART V. OF THE ANNUAL DEPARTMENTAL REPORT

FOR THE

YEAR ENDING JUNE 30

1906

PRINTED BY ORDER OF PARLIAMENT

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1907

CONTENTS.

LIST OF ILLUSTRATIONS.

Appendix 1.—Otto J. Klotz, LL.D.—Seismology.

Appendix 2.—J. S. Plaskett, B.A.—Instruments and Astrophysical Work.

Appendix 3.—R. M. Stewart, M.A.—Time Service.

REPORT

OF THE

CHIEF ASTRONOMER AND INTERNATIONAL BOUNDARY COMMISSIONER.

DEPARTMENT OF THE INTERIOR,
DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA, October 9, 1906.

W. W. CORY, Esq.,
Deputy Minister of the Interior,
Ottawa.

SIR,—I have the honour to present the report of the Astronomical Branch of the Department of the Interior and of the International Boundary Surveys, for the past year.

The correspondence from July 1, 1905, to June 30, 1906, was as follows:—

Letters received (exclusive of circulars, &c.)	1,124
Letters sent (exclusive of circulars, &c.)	2,087
Accounts dealt with	672

The expenditure, including salaries of all temporary employees, was $131,000, of which $96,745.44 was on account of boundary surveys.

The work of the photographer was as follows:—

Survey plates (developed). 4¾ x 6½	886
" " 5 x 7	106
Films, 3¼ x 5½	603
" 4 x 5	72
" 5 x 7	133
Copies of maps and plans, 4¾ x 6½	68
" " 8 x 10	69
" " 11 x 14	26
" " 14 x 17	9
" " 16 x 20	121
Lantern slides, 3¼ x 3¼	170
Black and white (prints and negatives), blue prints, 16 x 20	2
" " " 18 x 22	2
" " " 30 x 40	14
" " " 40 x 60	6
Bromide prints (contact and enlargements), 11 x 14	47
" " 16 x 20	352
" " 30 x 40	7
" " 10 x 14	2,824
" " 9 x 36	45
Argo paper prints (contact), 4 x 5	295
" " 4 x 6	1,618
" " 4¾ x 6½	145
" " 5 x 7	2,013
" " 8 x 10	220
" " 10 x 14	4
From April 1, seismograph record sheets developed	61
Total	9,918

The library now contains 2,053 volumes, comprising standard works on mathematics, astronomy, geodesy, physics, &c., and many scientific periodicals, reports of observatories, societies, and scientific operations.

The time service has been operated successfully during the year. Some few additions have been made to the number of dials operated in the government buildings. The signal for firing the noon gun on parliament hill is now given from the observatory, and a noon signal is also given at the city offices of the Great North Western Telegraph and the Canadian Pacific Telegraph, when desired. Arrangements are making for the installation of the electric dials, including a large one for the tower at the city post office. Some improvements have been made in the time apparatus in the observatory, which are detailed in the appended report by Mr. Stewart.

The fifteen-inch equatorial instrument has been under the charge of Mr. Plaskett, who has put in an electric control for the clockwork, and has improved the star spectroscope by addition of bracing for avoidance of flexure, and a covering box with automatic temperature regulation. Thus improved it is used for line of sight determinations. The solar camera, with negative lens, has been adapted for attachment to the eye end of the telescope and is used for photographs of the sun. Photometric observations on stars have been made by Mr. Tobey with the wedge photometer, and with the stellar camera. A full report by Mr. Plaskett on these instruments, their adjustments and use, will be found in appendix 2.

The number of visitors to the observatory during the year has been 4,402. The Saturday 'open' night for the public to look through the large telescope has been continued.

Designs for a coelostat house behind the main building have been prepared in the Department of Public Works, and it is expected that construction will shortly be begun. It is intended to instal in this building the 20-inch coelostat which was purchased last year for the eclipse expedition to Northwest river. The solar rays will be reflected through a tunnel to a room in the basement of the observatory, where the image can be examined spectroscopically.

The transit house, the construction of which was begun last year, has been practically completed, except for the piers, which it was thought advisable not to build until the instruments to be placed on them were ready for installation. The principal instrument, the meridian circle, is under construction in England, and is expected shortly.

The seismograph was set up in January in the room which had been provided for it in the basement. It is a two-pendulum instrument by Bosch, of Strassburg, registering two right angled components of the horizontal displacement photographically, on paper moving at a speed of 90 cm. per hour. The instrument has been under the charge of Dr. Klotz. A considerable number of earthquake shocks have been recorded, notably the great San Francisco earthquake of April 18 last. Unfortunately an interruption to the series of observations has occurred through taking up the floor of the room to put in additional drains, which were found necessary on account of dampness. The instrument is now in working order again.

The difficulties attending the repair of instruments, and the making of minor attachments or appliances have been lessened by the use of tools and machinery in the workshop. Recently a mechanician has been appointed.

The determination of latitude and longitude of points in Canada has been continued to fill requests for geographical positions made by the geographer of the department, and by the Georgian Bay Canal Survey. Since the date of my last report Mr. F. A. McDiarmid has made the necessary field observations at the following places:—

New Liskeard, May-June, 1906, latitude and longitude.
Rivière Ouelle wharf, June, 1906, latitude and longitude.
Maniwaki, July, 1906, latitude and longitude.
Cliff street observatory (second determination), May, 1906, longitude.

The longitudes of these stations have been determined by exchange of time signals

with the temporary transit house at this observatory, Mr. R. M. Stewart taking the time observations here.

The geographical work was interrupted by the necessity of sending Mr. McDiarmid to the Yukon in connection with the determination of the 141st meridian. Since his return he has again taken it up.

These astronomical determinations serve a useful purpose in the correction of maps, when the scale of these is not too large. For the control and checking of topographical surveys they are deficient. This is due to the fact that the astronomical and the geographical co-ordinates of the same point are not necessarily, nor usually, the same. The application of astronomy to topographical purposes proceeds on the assumption that the earth is a true spheroid and that the vertical line at a place (the direction of which it is the part of latitude and longitude observations to determine), is a true normal to it. This assumption is only approximately true: the irregularities of the earth, both above and beneath the surface, by their attractions, cause 'local deviations of the plumb line,' so that astronomical positions, though accurate in themselves within a few feet, may show a discrepancy in comparison with survey measurements of very considerable amounts.

Thus astronomical positions are to be used with caution in the control, in testing the accuracy of surveys made with any degree of precision. Their utility has regard rather to general maps, based on a number of local surveys, in controlling compilation. These surveys, each accurate within limits prescribed by its immediate purpose, will yet in general, as experience shows, be subject to errors of scale or distortion. When a general map is compiled by building up these surveys the separate errors tend to accumulate until the aggregate becomes sufficiently greater than the uncertainty, from the cause mentioned, of the astronomical observations. In such case these may be applied to correct the compilation.

It has been thought well to emphasize this point, since the relation of astronomical observations to surveys is frequently misunderstood, and corrections often misapplied.

There is still a wide field for astronomical determinations in Canada, both in correcting general maps compiled from local surveys not co-ordinated, and in affording new points of departure for geographical surveys in unsurveyed regions. They cannot serve as control for topographical surveys of any degree of minuteness of detail. This is the function of the trigonometrical survey.

The trigonometrical survey has been carried on during the last year in the country between the Ottawa and the St. Lawrence rivers, southerly and eastwardly from the city of Ottawa. The general plan is the laying out of a network of quadrilaterals with sides 15 to 20 miles long. It is desired to carry this network eastward parallel to the 45th parallel as far as the Maine boundary.

While in general the triangulation will be 'secondary,' having for purpose the establishment of control for topography, a selection will be made of quadrilaterals to be observed as a primary chain, which can be connected with the United States Coast and Geodetic Survey and the United States Lake Survey triangulation.

The work on the triangulation has so far been confined to the selection of points and the erection of stations thereat for the angular observations. The building of high framework for the observing stations has been found generally necessary in this section of the country, on account of the small elevation of the hills, and the frequent occurrence of timber. The erection of these frameworks is in the hands of Mr. J. D. McLennan, under the supervision of Mr. C. A. Bigger. A beginning has also been made in the carrying on of lines of geodetic levelling, which is a necessary concomitant of the triangulation, so as to obtain the vertical, as well as the horizontal co-ordinates of the stations.

BOUNDARY SURVEYS.

The resurvey and remarking of the international boundary line along the 49th parallel, by Mr. J. J. McArthur, in conjunction with Mr. Sinclair, of the United States Coast and Geodetic Survey, has been continued.

Mr. McArthur's operations have been on the section of the line in the Cascade mountains, and thence westerly in the valley of Fraser river. This section is throughout extremely difficult to survey, being very mountainous and densely wooded on the mountain slopes and lower lying lands. Since the party is still in the field, a report of the amount of work completed cannot be furnished.

It is with very great regret that I record the death of Mr. Howell Bigger, who was employed on this work. He was a young man of great promise, an honour graduate of McGill University in the engineering course, an Ontario land surveyor and a Dominion land surveyor. He was appointed to this branch by order-in-council of May 31, 1904. He had the duty assigned to him of carrying on the triangulation along the boundary line, a duty which he performed carefully and energetically. He also last winter made the triangulation connecting the old and the new observatories in Ottawa. While working near Huntingdon, B.C., in the early part of June he was attacked by appendicitis. Distance from proper medical care, coupled with his unwillingness to leave his work, led to fatal delay. He was taken to Vancouver hospital and operated upon on June 6, but too late. After lingering a month he died on July 7.

Dr. R. A. Daly has continued his geological investigations along the 49th parallel west of the Rocky mountains, and collections of the fauna of the region have been made under the direction of Mr. J. M. Macoun.

The survey of the Canada-Alaska boundary line under the Award of 1903 and the supplementary agreement of March 25, 1905, has been continued.

The distribution of the survey work on this boundary line during the present season has been as follows:—

One Canadian party under Mr. A. J. Brabazon, D.L.S., in the vicinity of the Alsek river.

One Canadian party under Mr. W. F. Ratz, D.L.S., in the vicinity of Taku river.

One Canadian party under Mr. J. D. Craig, D.L.S., in the vicinity of Whiting river.

An attaché, representing the United States Commissioner, accompanied each of the two last mentioned parties.

One United States party has been working eastward from Yakutat bay towards the Alsek river, and three parties at the crossing of Chilkat river, the Chilkoot and White passes, and southerly from the latter pass.

Mr. George White-Fraser, D.T.S., has been my representative with the United States surveyors operating in the Lynn canal region.

As a result of the examination which was made last year into the condition of the monuments marking the boundary line eastward from Richelieu river to St. Croix river, an agreement was made between the United States and British governments for the resurvey and remarking of this section of the boundary line, in the same way as had been agreed to in regard to the 49th parallel. I was named for commissioner on behalf of His Majesty by order-in-council of July 7, 1906. Mr. O. H. Tittmann was appointed to a similar position for the United States.

With the concurrence of the Minister, I appointed Mr. G. C. Rainboth, D.L.S., as engineer in command of the Canadian share of the survey, and Mr. J. B. Baylor, of the United States Coast and Geodetic Survey, was appointed to a similar position by Mr. Tittmann.

The survey was commenced at Hall's stream, at the northeast corner of the state of Vermont, about the beginning of August, and is now in progress, proceeding westward from the initial point.

The work consists of cutting a vista through the forest, which is fairly dense where the operations are now going on, chain measurements along the line, making a plane table sketch of the adjacent topography, running a line of levels along the line, and setting the monuments.

For monuments, preference was had for granite monuments similar to those placed along the Quebec-New York line in 1902, but consideration of cost of conveyance of the monuments in the hilly country to the points where they will be needed,

resulted in a decision to use the old cast-iron monuments, when they were in good condition, resetting them in large concrete bases, and to place granite or concrete monuments only where the old monuments were broken or missing, or where additional monuments were needed.

A fourth boundary commission has become necessary with the ratification of the recent convention between the United States and Great Britain for the survey and demarcation of the 141st meridian. This meridian, under the terms of the Treaty of 1825, between Great Britain and Russia, forms the boundary between Canada and Alaska from the point where the Award boundary of 1903 terminates, near Mount St. Elias, to the Arctic ocean. The convention provides for the appointment of one commissioner by each country, whose duties shall be to determine the meridian in question where it crosses the Yukon river, and to survey and mark the line north and south from that point.

I was nominated as His Majesty's commissioner by order-in-council of July 23, 1906, and Mr. Tittmann has been appointed on behalf of the United States.

Since the observations for longitude could be made in summer time only, our first action was to arrange that these should be made immediately, so that actual survey of the line, for which there is reported to be pressing need, could be begun early next spring.

The telegraph line from Dawson, Yukon, to Fort Egbert, Alaska, follows the Yukon river, across the meridian. From Dawson, communication with the south is had by the government line to Ashcroft, B.C., and thence by the Canadian Pacific Railway telegraph to Vancouver. Fort Egbert is connected by a telegraph line built by the United States government with Valdez, Alaska, from which communication is had with Seattle by cable. The longitude of Vancouver had already been determined by observations which are printed in my report of last year. That of Egbert was determined by the United States Coast Survey in 1905. A double determination of longitude at the meridian from both sides was therefore possible, and was decided upon. Mr. Tittmann sent an observer, Mr. Smith, to Fort Egbert, while I detailed Dr. Klotz for the Vancouver observations and Mr. F. A. McDiarmid for those at the presumed location of the 141st meridian. The observations have lately been completed.

An interesting point in connection with this is the fact that on the line between Vancouver and the 141st meridian there were four 'repeaters.' A repeater is a combination of relays whereby signals are automatically transmitted from one section of a line to another for the purpose of better utilizing battery power. From the construction of a repeater there is no certainty that the time of transmission of signals in opposite directions through it will be equal, and any difference in this time would affect the resulting longitude by half of its amount.

Not being aware of any previous experiments to determine the amount of this uncertainty, and recognizing the necessity of either estimating or eliminating it in such an important longitude determination as this, I had some experiments made with a repeater, which showed that the effect was measurable, and might become, though apparently only through a forced adjustment, large enough to be comparable with the probable error of a time determination. After some consideration, I advised the observers to make two exchanges of time in the one evening, directing the operators at repeating stations to reverse their repeaters between the exchanges. This reversal, if done without change of adjustment, should approximately at least eliminate the error from the mean of the two exchanges.

Appended to this report are the following sub-reports, namely:—

Appendix 1.—Report by Dr. Otto J. Klotz, on seismographic and magnetic work, and determination of the 141st meridian.

Appendix 2.—Report by J. S. Plaskett, Esq., B.A., on observatory instruments and astrophysical work.

Appendix 3.—Report by R. M. Stewart, Esq., M.A., on time service

Appendix 4.—Report by J. Macara, Esq., on longitude and latitude work.

Appendix 5.—Report by R. A. Daly, Ph.D., on the geology of the mountains crossed by the international boundary (49th parallel).

I have the honour to be, sir,

Your obedient servant,

W. F. KING,

Chief Astronomer and International Boundary Commissioner.

APPENDIX 1

REPORT OF THE CHIEF ASTRONOMER, 1906.

SEISMOGRAPHIC AND MAGNETIC WORK

AND

DETERMINATION OF THE 141st MERIDIAN

BY

OTTO J. KLOTZ, LL.D.

CONTENTS.

ILLUSTRATIONS.

APPENDIX I.

REPORT OF OTTO J. KLOTZ, LL.D., ON SEISMOGRAPHIC AND MAGNETIC WORK, AND DETERMINATION OF THE 141ST MERIDIAN.

OTTAWA, ONT., October 31, 1906.

W. F. KING, Esq., B.A., LL.D.,
Chief Astronomer, Ottawa.

SIR,—I have the honour to submit the following report for the year 1906, of work carried out under my charge: (1.) The Seismological record; (2.) the determination of the 141st meridian, being a part of the boundary line between Canada and Alaska.

SEISMOLOGY.

As this is the first report on the seismograph recently installed in the Observatory, it may be opportune to give a brief sketch of the progress made in the study of seismology, one of the newer branches of science and the evolution of instruments in connection therewith.

Earthquakes have been existent upon the earth since the formation of the crust and will continue with ever diminishing force until the earth passes into a state of 'rigor mortis.' In the earlier writings are found records of quakes and tremblings of the earth, and as the belief was held that the solid crust of the earth floated on a liquid, the motion caused by an earthquake was supposed to be undulating, resembling the rolling of the sea. However, another motion was soon recognized—a succussatory one, one as if transmitted through a blow.

It is but natural that the ancients, being familiar with volcanoes, should associate all seismic disturbances to a volcanic origin. The systematic study of earthquakes, however, began only within the past sixty years, and systematic observations with suitable instruments, are of still more recent date. One of the early classics on the subject is by R. Mallet 'On the dynamics of earthquakes,' Transactions Royal Inst. Academy, Vol. XXI., 1846.

Japan is the country par excellence for earthquakes, and here we find the study of seismology to have received its greatest impetus, since 1880, both from the scientific and practical standpoint, through the labours of Milne, Ewing, Gray, Omori, Sekiya and others. The study of earthquakes prior to this period was, for lack of instrumental records, more or less academic and theoretic.

There is no branch of science in which co-operation is more essential for ultimate success than Seismology. It is only by the study of carefully obtained records from different places, widely scattered, of the same phenomenon that we can hope to elicit answers to the many questions that confront the seismologist. To make records valuable they must be comparable, and this again is best obtained when similar instruments and methods are adopted. To meet this want there has been organized 'The International Seismological Association,' with its headquarters at Strassburg in Germany. Practically all civilized countries are members of this association and contribute proportionately towards its support. It is intended to hold meetings about every four years, which will be attended by the duly accredited scientists from the various contributing countries. If the progress made during the last decade in the study of seismology is maintained, many difficult problems will soon be solved.

In the consideration of earthquakes we deal with the earth as an elastic body and the waves propagated by the seismic disturbance due to this elasticity, in contradistinction to the undulating motion of water due to gravity. When the motion of the particles is at right angles to the line of propagation we speak of transverse waves, and when it is in line with or parallel to the direction of propagation we speak of longitudinal waves. In the latter case there is compression and expansion of the moving particles.

The movements of the earth's crust are distinguished as Bradyseisms and Tachyseisms, the former being slow movements caused by the diurnal and seasonal heating of the surface; also to barometric pressures, and the attraction of the sun and moon producing tidal effects upon the solid surface of the earth similar to that on water. The latter, tachyseisms, are more rapid, and are subdivided into microseismic and macroseismic disturbances. Of these subdivisions the former is only recognizable by instrumental means, while the latter is the phenomenon observed directly by our senses at or near the epicentre or earthquake. The microseisms we may say are the echoes of the macroseisms or earthquake.

To the most casual observer it is evident that the earth's surface or crust has been subject to movement. Deep down in the earth are found fossil remains, of vegetable and animal nature, indicative of submergence, while on the other hand on the heights of mountains are found marine fossils showing that the land has risen from the ocean bed. Again the sedimentary rock formations which were deposited originally in horizontal layers are found tilted, dislocated, ruptured, faulted, intersected by dykes of the solidified molten magma from the interior. All these phenomena are due to movements of the earth's surface. Many causes conspire to produce these results and the ever restless forces of nature are continually moulding the earth into a shape and figure best suited to satisfy the contending elements. Through atmospheric action by rain, frost and wind, denudation takes place; mountains are slowly ground down and the material carried to the sea by the rivers, lightening the land surface and burdening the ocean bed, whence stresses and strains are set up. Again the earth is a cooling body, and must contract. The outer shell as a rigid mass tries to accommodate itself to the shrinking interior with the result that crushing, crumpling and rupture must take place.

It may be worth while noting here that the theory advanced by Lowthian Green some thirty years ago of a tetrahedral earth is again receiving attention.* Briefly the theory of a tetrahedral earth is based on the following considerations. A given volume when confined within a sphere has the least surface, and when confined within a tetrahedron has the greatest surface, that is, of all regular solids, for a given volume the tetrahedron has the greatest surface. Now, the sphere is the form that a body will assume when the particles are free to move and are only acted upon by gravity. Such a revolving sphere, with the added centrifugal force, becomes an oblate spheroid. The angular velocity of rotation being uniform and constant the whole body would be in stable equilibrium. If now any force or forces are brought into play to disturb this equilibrium, stresses and strains are set up, and a counter tendency to relieve these stresses and strains is called forth to set up equilibrium. It is at this juncture that the property of the tetrahedron comes into play. Taking as the principal disturbing force of our supposed liquid or molten spheroid of revolution, that of dissipation of heat or cooling process, we find that the crust or shell of the earth tries to adjust itself to the stresses and strains set up by the contracting body, and does so by the line of least resistance, that is, by spreading the stresses and strains over the greatest surface, with the result, that the tendency of the surface of the earth is to assume the tetrahedral form, *i.e.*, of an equilateral pyramid. Or one may say that the contracting earth changes into that form whereby the original superficial area is maintained. For equal surfaces the volumes of the sphere and tetrahedron are to each other as 1: .55; and for equal volumes the surfaces are as 1: 1·449.

*Arldt: Beiträge zur Geophysik, VII. Band, 3 Heft.—1905.

Neither the theory nor its advocates gives us a four-cornered earth, its original condition and axial revolution would prevent that, but the theory does claim that the tendency, however slight or great in effect, must be towards shaping the surface into that of a tetrahedron, or tetrahedroid, the latter having curved surfaces and edges. A good idea may be found of the effect of the change produced upon the earth by the change to or towards the tetrahedral form, if we take a globe of the earth and surround it by a tetrahedron, of equal volume, made of cardboard, with circular openings symmetrical on the four faces for the protruding sphere. Taking the axis of the earth coincident with an axis of the tetrahedron through one of its apices, the south pole, we have the opposite face over the north pole. In the cooling and contracting earth the protruding parts of the sphere through the four faces of the tetrahedron will tend to approach the surface of the tetrahedron, that is, will be depressed and become thereby water areas, or oceans, while the protrusions, land, will be towards the edges of the tetrahedron. If a complete transformation from the sphere to the tetrahedron took place, which is of course impossible, we would have a north polar sea, which is the case, three great equatorial oceans, a south polar land cap, which too is the case, and there would be six grand mountain ranges, three diverging from the south pole, and the other three encircling the northern hemisphere. This ideal condition does not obtain, but still there are many interesting facts in keeping with the tetrahedral theory.

In the tetrahedron every corner has a surface opposite to it, so that for the earth this would mean that land and water are antipodal, which is fairly well represented in the actual conditions. Another result would be that the land masses would be broad in the northern hemisphere and taper towards the south, which too agrees with our geography. Inversely, the oceans should contract towards the north, a condition fairly well borne out.

The north polar area being represented by a surface of the tetrahedroidal figure, and the south polar one by a corner, it would follow that the flattening of the earth in the southern hemisphere would be less than in the northern, and furthermore that gravity would increase less rapidly towards the south pole than towards the north pole. Both these considerations have been confirmed by geodetic and pendulum observations.

The effect of the rotation of the earth counteracting the tetrahedral tendency would be most effective in the equatorial regions, and hence the tetrahedral phenomena or condition most marked in higher latitudes. The oceans of the four faces would represent depressions on the original sphere and hence be brought nearer the earth's centre with a consequent increase of gravity. Pendulum observations have shown that there is in general an excess of gravity in the great oceans.

As Arldt in his concluding paragraph says: 'The tetrahedral theory appears at first sight rather peculiar, however, an unbiased examination will show that in its broad outlines and features it meets the configuration of the earth very well.'

The tetrahedral form requires the antipodal position of land to water; the three-sided symmetry of the earth; as well as convergent land and sea areas. The theory explains the difference in flattening at the north and south poles, and the variation of gravity, other than from a spheroidal form. In short, so far no proof has been advanced to make the theory untenable.

We may refer to another theory of the figure of the earth, contained in a paper presented by J. H. Jeans to the Royal Society in 1902.* 'It seems to be almost certain that the present elastic constants of the earth are such that a state of symmetrical symmetry would be one of stable equilibrium. On the other hand, if we look backward through the history of our planet, we probably come to a time when the rigidity was so much that the stable configuration of equilibriums would be unsymmetrical. At this time the earth would be pear-shaped, and the transition to the present approximately spherical form would take place through a series of ruptures.

* Nature, Vol. LXVII., p. 190.

It is suggested that the earth, in spite of this series of ruptures, still retains traces of a pear-shaped configuration. Such a configuration would possess a single axis of symmetry, and this, it is suggested, is an axis which meets the earth's surface somewhere in the neighbourhood of England (or possibly some hundreds of miles to the southwest of England). Starting from England, we find that England is at the centre of a hemisphere which is practically all land; this would be the blunt end of our pear. Bounding the hemisphere we have a great circle, of which England is the pole, and it is over this circle that earthquakes and volcanoes are of most frequent occurrence. Now, if we suppose our pear contracting to a spherical shape, we notice that it would probably be in the neighbourhood of its equator that the changes in curvature and the relative displacements would be greatest, and hence we should expect to find earthquakes and volcanoes in greatest number near to this circle. Passing still further from England, we come to a great region of deep seas—the Pacific, South Atlantic, and Indian Oceans; these may mark the place where the 'waist' of the pear occurred. Lastly, we come, almost at the antipodes of England, to the Australian continent. This may mark the remains of the stalk-end of the pear.'

We cannot in this place pursue this subject of the figure of the earth any farther; it was only alluded to to show one of the factors—the contracting forces, ever active whereby stresses and strains are set up and without which no earthquakes are possible.

Fisher in his 'Physics of the Earth's Crust,' 1889, combats the theory of mountain building as being due to the secular cooling of the earth and the accompanying contractions. Arrhenius in his 'Lehrbuch der Kosmischen Physik,' 1902, considers the crust of the earth comparatively thin, at a depth of about 40 miles to merge into a hot fluid mass, the magma, due to the increasing temperature. From the deepest boring on the earth the increase of temperature is about 1° F. for 51 feet,or say 100° per mile. Beyond a depth of about 200 miles the magma assumes the gaseous form. 'The physical difference between these three conditions is not very great on account of the viscosity of the magma as well as of the gases (due to pressure), but they practically behave as solids under deforming forces of not too long duration.' Further on he writes: 'The earth, as well as the sun, contracts, whereby heat is evolved and the contraction partly arrested or decreased. Nevertheless the earth slowly shrinks. This pertains especially to the interior of the earth, for the temperature of the surface is almost wholly due to radiation from the sun, and in a small degree upon the character of the atmosphere. It may be assumed that, broadly speaking, the radiation of the sun and the nature of the atmosphere are constant. It follows, therefore, that the crust of the earth will not follow the shrinking of the interior. Foldings and wrinkles will be found, and it is the general conclusion, that this is the principal reason for the uplifts of the surface into mountain chains.'

That earthquakes are due to an adjustment of stresses in the earth's crust is admitted by all investigators, but on the cause of the stresses set up, there is far from unanimity of opinion. Restless nature has so many forces at work, that there are many agencies by means of which the same or similar results may be produced. Hence a correctly interpreted phenomenon as to its origin and cause, will not necessarily give the proper explanation for a similar phenomenon. This manner of interpretation seems to have been the case especially with the 'Einsturztheorie,' whereby earthquakes were ascribed and correctly in some cases, as due to the downfall or collapse of a part of the earth's crust into hollows or caves. These hollows within the earth are due to the action of water in dissolving and carrying away the more or less soluble parts of the rock formations. From this it would follow that regions underlain by chalk, limestone, or gypsum formations with the necessary subterranean water courses, would be those most subject to earthquakes. This can scarcely be maintained as in accordance with facts. Mohr in his 'Geschichte der Erde,' 1866, would explain all earthquakes as due to downfalls. He adduces many instances in support of his theory, beginning with the well-known catastrophe at Lisbon, on

November 1, 1755. In support of his contention he draws attention to the fact that the sea first receded, and later the tidal waves rolled in, with a depth of fifty feet above the normal. Furthermore he adds that the tremor was felt before the destructive wave arrived. All this is of course obvious for a downfall or collapse of the bottom of the ocean off the mouth of the Tagus. He cites many other instances, especially along the western coast of South America, in support of the existing theory, showing that the adjoining coast strip must have risen, as it did, due to the collapse in the bottom of the sea and to the landward thrust of the heat energy evolved by the downfall.

It is undoubtedly difficult to conceive large caves within the earth, especially as existing at any great depth on account of the enormous burden of the superincumbent mass. Caves which are near the surface cannot be the cause of far reaching earthquakes, and the deeper we go to extend the disturbed area the less probable is the existence of any large cave. As Dutton in his 'Earthquakes,' p. 20, says: 'The downthrow theory cannot claim full acceptance beyond those instances where the evidence of the downthrow is patent to every eye upon the surface of the ground, when the instantaneous sequence of the earthquake is attested by satisfactory evidence.'

A popular belief of the cause of earthquakes is volcanic activity. This, however, on examination of the actual disturbances and outbreaks, proves to be true only within narrow limits, *i.e.*, the earthquakes when they do accompany a volcanic eruption are confined within a rather restricted zone, and are never 'world shaking.' The case of the destructive earthquake at Casamicciola, on the island of Ischia, in 1883, may be mentioned as an instance of the above. 'The town of Casamicciola was utterly wrecked, only one house being left standing, and the number of people killed by the falling ruins was nearly 1,900. Yet in Naples, only 22 miles distant, the shock was noticed only by a few people as a faint tremor.' It may be interesting to quote from Strabo with reference to this unfortunate island. In his fifth book in geography he writes: 'That the Epomean hill on the island was shaken, vomited fire, and the water of the sea receded three stadia, but shortly returned with a tidal wave that flooded the island.'

Milne, one of the foremost of seismologists, and who has made an exhaustive study of Japanese earthquakes, writes, 'Seismology,' p. 30. 'To produce earthquakes which are felt over areas of five or ten thousand miles, and which give rise to waves which may be recorded at any point upon our globe, it is difficult to imagine how the primary impulse could have originated at a volcanic focus. Volcanic explosions, as we see them, seem to result from the concentration of subterranean energy at a point, while to shake the whole surface of our globe it would appear necessary that the initial effort should be exerted on a surface very much larger than we can reasonably suppose to exist beneath a volcano . . . . An analysis of some 10,000 earthquake observations in Japan shows that there have been but comparatively few which had their origin near to the volcanoes in the country.' Volcanoes are shallow-seated and the disturbances caused by them are of limited areal extent.

Although some earthquakes are due to downfalls, and local ones to volcanic eruptions, yet for the great majority another reason or reasons must be found. Of the latter, the contracting force, already alluded to, is the one first to suggest itself, and has for its support at least great plausibility. However, it has been combated by able investigators, without, however, being able wholly or satisfactorily to dispose of it completely.

Let us picture to ourselves the earth at any given time in a state of perfect equilibrium, *i.e.*, isostasy, there being no stresses on its surface nor in the crust. Let us note the physical features, the heights of the mountains, the faulting and folding of the rock formations, the depths of the ocean and the distribution of land and water. Now let the atmospheric influences come into play, rain and snow, heat and cold, together with varying atmospheric pressure. The pre-existing equilibrium will be immediately disturbed, the water, as ripples, creeks, rivers and streams will begin its work of erosion and denudation; heat and frost will assist in the disinte-

gration of mountain masses, and the ocean beds adjoining the continents will be loaded by enormous amounts of detritus carried from the land. Unless there is a continuous and simultaneous adjustment of the change of pressure, the stresses set up will be cumulative, and continue so until they exceed the limit of elasticity when rupture must take place to restore equilibrium for the time being. Rupture would necessarily be accompanied by earthquakes.

It is obvious therefore that meteoric or atmospheric influences are capable of setting up stresses on the earth's surface. It is safe to say that the whole surface of the earth is in a constant tremor due to stresses. But besides this general condition, there are other factors which come into play, and localize in a measure the seismic disturbance. These are mountain masses and oceanic depths, especially if these are contiguous. Speaking generally, mountains are not masses resting upon the surface of the earth, but must be considered as masses immersed in the earth, just as an iceberg is immersed in the water. The greater the part that projects above the water, the greater must be the part beneath the surface, for the amount of water displaced must be equal to the floating mass, otherwise there would not be equilibrium. Somewhat similar it is with the mountains. Were they resting on the surface, the stresses set up by the superimposed mass would not only be enormous, but would be greater than the crust could support. Furthermore as a superimposed mass it would materially affect the force of gravity in the adjoining region. The most noted investigation of this question was with reference to the attraction of the Himalayas in connection with the Great Trigonometrical survey of India. Pendulum observations have shown conclusively both in India and America that this is not the case. However complete equilibrium or isostasy, does not obtain, and hence the residual stresses and strains.

Other things being equal, with great mountain masses denudation must be relatively greater than with those of less magnitude, on account of the greater erosive action in the former, with a consequent decrease in the downward pressure of the mountain mass, and an increase by the transported material on the adjoining ocean bed.

Here we have then a cycle of stresses and strains established between the land and ocean with a deep-seated inflow from the sea towards the land, land-raising or mountain-building in its character. These changes are continuously taking place, the earth's crust and surface is undergoing constant transformation, however minute; the stresses and strains are continually responding to one another, vast rock formations that seem rigid, are by the slow process of time bent and contorted as if made of wire. But when these responses are not synchronous, when there is a lag, equilibrium can only be restored by rupture. The rupture will be along the line of least resistance, and this is generally found in a geological fault, an old rent in the crust. This line of weakness is not necessarily visible or apparent upon the surface of the earth.

No country is absolutely free from earthquakes, but such where the surface geology shows the older or archæan rocks, earthquakes are fewer and of less severity. On this score the eastern part of our Dominion may feel pretty safe from any catastrophe due to earthquake. As to distribution of earthquakes over the earth, Milne writes, p. 31: 'Throughout the world we find seismic energy is most marked along the steeper flexures in the earth's crust, in localities where there is evidence of secular movement, and in mountains which are geologically new and where we have no reason for supposing that bradyseismic movements have yet ceased.

As examples of the flexures to which reference is here made, we may take sections running at right angles to the coast lines of the various continents. The unit of distance over which such slopes have been measured is taken at 2 degrees, or 120 geographical miles. The following are a few of such slopes:

West Coast, South America, near Aconcagua.. ..	1	in	20·2	Seismic Districts.
The Kuriles from Urup..	1	"	22·1	
Japan, west coast of Nipon..	1	"	30·4	
Hawaiian Islands, northwards	1	"	23·5	
Australia, generally....	1	"	91	Non-Seismic Districts.
Scotland from Ben Nevis	1	"	158	
South Norway..	1	"	73	
South America, eastwards	1	"	243	

The conclusion derived from this is that if we find slopes of considerable length extending downwards beneath the ocean steeper than 1 in 35, at such places submarine earthquakes, with their accompanying landslips, may be expected.'

Although long ago it was observed and known that macroseismic earthquakes were confined almost wholly to coast strips, yet it is only comparatively recently that the relationship of depth or slope of the ocean bed and adjoining littoral to the seismic disturbance has been established. Destructive earthquakes in the interior of contients whether in the Americas, Europe, Asia, Africa or Australia are practically unknown. It would appear, therefore, that the more accurately we have the ocean bed charted, the adjoining topographic features, or orography, being pretty well known, the more accurately will the area most likely to be subject to seismic disturbance be known.

From statistics collated by de Ballore it appears that there are annually about 3,800 macroseismic disturbances, that is, such that can be directly noted by the senses. This means that there is a sensible earthquake nearly every two hours. As there is a large region of the earth, both on land and water, from which no records are obtained, the actual number must in reality be above the one quoted. There are now close on 150,000 earthquakes recorded. Milne estimates that of the smaller earthquakes, or microseisms, 30,000 take place every year, 'each of which disturb ten up to several hundreds of square miles of the earth's surface, and would be sufficiently intense to be felt by many people.'

'The former or macroseisms represent a disturbance, not only of the crust of the world, but also of the homogeneous nucleus it covers, and are the result of sudden accelerations in the process of rock-folding accompanied by faulting and molar displacements of considerable magnitude, whilst the latter appear to be shiverings within the crust, and are for the most part settlements and adjustments along the lines of their primary fractures.'

With the increase of seismographs, or recording instruments, our knowledge of the occurrence of the smaller earth movements will be greatly increased, and the relationship between the existing faults and fissures and disturbances more clearly established. Calamitous, destructive and cataclysmic as earthquakes have been in historic times, yet as terrestrial phenomena these historic earthquakes or the ones since the advent of man upon the earth, are vanishingly small disturbances compared with those that have taken place in the earlier history of the earth. The surface of the earth becomes dislocated a few feet and we find it followed by wreck and ruin. The phenomenon is to man a catastrophe, villages, towns and cities are destroyed, yet the earth has scarcely manifested that it is not an absolutely dead and inert body. Relatively far greater phenomena take place on the surface of a cooling cast cannon ball, or in a day on the surface of an orange by drying. A foot represents but the one-twenty-millionth part of the radius of the earth, and yet how destructive such a small quantity can be when manifested by a sudden displacement in the crust of the earth, due to compensation and adjustment of forces active on and in the earth. The destructive action of earthquakes is greater in loose earth, 'made' ground, alluvium, gravel or drift than in fixed rock.

The depths of the hypocentre, the point or area from which the seismic disturbance is sent forth, have not as yet been satisfactorily determined. Generally, it may be said that the action is confined within a shell less in thickness than the hundredth part of the earth's diameter, say 40 miles.

Mechanical energy having been set free in the earth, it is propagated in all directions by spherical waves. The surface of the earth immediately above the disturbing origin, the hypocentre, is called the epicentre, and here the greatest motion is felt. If the earth were homogeneous and of uniform density, then the direction of propagation would be radially straight; this, however, not being the case, the direction suffers deflection, similar to refraction of a ray of light in passing through different media of an atmosphere, resulting in curved paths, the direction following the 'brachystochronic' curve, or line of shortest time from the hypocentre to the surface. The velocity through the denser part of the earth is greater than when approaching the surface. From this it follows that the wave surfaces are eccentric with reference to the hypocentre, the greater part of the surface being below the hypocentre, that is towards the centre of the earth. The surface of a wave cuts the surface of the earth in a line called an 'isochrone,' or 'coseist,' for points on this line would receive the disturbance at the same time. The line joining places where the intensity is the same is called an 'isoseist.' Different densities of the same depth, different formations, different coefficients of elasticity, besides dislocations, faults, dykes are factors which govern the form of the coseist. Theoretically it should be circular. Schmidt's investigations show that within a zone of the epicentral area the velocity of propagation upon the surface of the earth decreases up to the point of inflection indicated by his deduced conchoidal hodograph, and from there onward the velocity increases indefinitely with a consequent decrease in intensity. The point of inflection is dependent upon the depth of the hypocentre; the nearer the latter to the surface the nearer the point of inflection will be to the epicentre.

The true velocity of the wave is that of propagation from the hypocentre, while the apparent velocity is that along the surface of the earth. The latter is found from the linear measure between the coseists or isochrones. A geometrical construction of eccentric spherical surfaces about a hypocentre, drawn at unit intervals of time, say a minute, and intersecting the surface of the earth will make clear the apparent velocities upon the earth; and it will also show why the apparent velocity increases with distance beyond the epicentral zone. The shock at the hypocentre is sharp and short in duration. But it must be remembered that every particle set in motion, becomes itself a fresh centre of energy, sending out waves in all directions and thereby prolongs the disturbances felt or measured on the earth's surface, so that we may say, in general, the farther a place is removed from the epicentre the longer will be the duration of the earthquake. The epicentral area, which is the most disturbed, lying immediately above the hypocentre, after its surface is agitated from the hypocentre, in turn sends out pulsations along the surface of the earth, as transverse waves, those from the hypocentre being longitudinal, that is, the motion of the particles is in line with or parallel to the direction of the pulsation, while in the transverse the motion is at right angles or normal to the direction. If we consider the effect (microseismic and measured by a seismograph) of an earthquake at a distant station, it will be found that the longitudinal waves through the interior of the earth from the hypocentre will be the first to arrive pursuing the shortest line (brachystochrone) dependent upon the varying density and coefficients of elasticity of the earth. These first arrivals of the seismic disturbance are recognized on the instrumental record as 'preliminary tremors.' These 'first' preliminary tremors are followed by 'second' preliminary tremors due to the arrival of the slower transverse waves from the epicentral area. Together their duration is generally several minutes. Then comes the 'principal portion,' subdivided into 'initial,' 'slow period' and 'quick period' phases. The first of the longitudinal as well as the transverse wave is followed by others, until the piling of wave upon wave reaches a maximum, thereafter the energy slowly fades away, the record thereof being the 'end portion.' The wave systems set up by the infinite number of vibrating particles, in so many different mediums of different densities and elasticities is highly complex and difficult of analysis. Interference phenomena must and do occur, and are recognized on the seismograms. What actually occurs in and on the earth during an earth-

quake can only in the present state of seismology be treated in its broad outlines. To elucidate all the ramifications of the observed phenomena requires further study and a more intimate knowledge of the constitution of the crust of the earth. It may, however, be said that perhaps in no branch of science has more rapid progress been made than in this new one of seismology.

Arrhenius calls attention to the fact that when the first impulse passes through a considerable part of the liquid and gaseous interior of the earth, it is exceedingly weak. From this he concludes that the wave is greatly damped by the viscosity of the interior, which would not be the case were the interior a rigid body.

Laska has given a simple rule and expression for the determination of distant earthquakes:

'The difference of time between the first and second phases expressed in minutes decreased by unity gives the distance of the epicentre in 1,000 km. from the place of observation.'

Using symbols, let

V_1 = beginning of first phase (preliminary tremor).
V_2 = " second phase.
B = " principal part.
Δ = distance in 1,000 km.

The empirical formulæ are—

$$1+\Delta = V_2 - V_1 \qquad (1)$$
$$3\ \Delta = B - V_1 \qquad (2)$$

Hence—

$$B = V_1 + 3\ \Delta \qquad (3)$$
$$V_2 = V_1 + (1+\Delta) \qquad (4)$$

If we assume weight unity for the value of Δ in equation (1), that of (2) will be 3.

Hence we obtain the more accurate value—

$$\Delta = \frac{(B+V_2)-(2\ V_1+1)}{4} \qquad (5)$$

Applying these to the Ottawa record of the San Francisco earthquake of April 18 last, where from the east-west, north-south pendulums we have respectively:—

	h.	m.	s.	h.	m.	s.
V_1 =	8	19	25	8	19	12
V_2 =	8	24	48	8	24	40
B =	8	31	20	8	30	32

	m.		
From (1)	5·380 − 1,	Δ = 4380 km.	4466 km.
" (2)	11·93 ÷ 3,	Δ = 3980 km.	3777 km.
" (5)		Δ = 4080 km.	3950 km.

Mean.. .. ..Δ = 4015 km.

Taking the geographic co-ordinates of San Francisco and Ottawa, the distance between the two places on a great circle is 3940 km.

As the epicentre lies a little to the west of San Francisco, the distance of the epicentre as determined from the Ottawa record above is satisfactory.

This relationship of the times of the different phases of an earthquake, as shown on seismograms, to the distance of the epicentre is a very important discovery or deduction from a large number of records. It is impossible from the seismograms to determine to the absolute individual second the time of any particular phase. This uncer-

tainty amounts in the average to about sixty kilometres in the deduced distance of the epicentre.

The middle ordinate to the chord connecting the two places is in round numbers 190 miles, say 300 km., and measured to the line joining the hypocentre, which is directly beneath the epicentre it will probably be 10 km. more. However, if the first impulse follows the shortest route of transmission, as it necessarily will, we find that the path of the first wave, being concave to the surface, will lie centrally considerably over 300 km. below the surface of the earth. This distance is greater than any quantity that has been assigned as the thickness of the crust, and hence penetrates into the mass that has been given the more or less vague term of 'magma.' Hayford in his recent (1906) valuable and important investigations of 'The Geodetic Evidence of Isostasy,' finds 71 miles (114 km.) as the most probable value for the depth of compensation, that is, the depth at which 'the compensation of the excess of matter at the surface (continents) by defect of density below, and of surface defect of matter (oceans) by excess of density below' is complete. 'At and below this depth the condition as to stress of any element of mass is isostatic, that is, any element of mass is subject to equal pressures from all directions as if it were a portion of a perfect fluid.' From this it appears that the behaviour of the magma, being situate beyond 71 miles, is that of a liquid.

The chord whose middle ordinate is 71 miles would subtend an angle of 21° 40′, or say 1,500 miles upon the surface of the earth, so that for places at a greater distance than 1,500 miles from the epicentre the preliminary tremors must pass through the magma. As earthquakes are so intimately bound up with stresses, we quote Hayford: 'In terms of stresses, it is safe to say that these geodetic observations prove that the actual stresses in and about the United States have been so reduced by isostatic adjustment that they are less than one-tenth as great as they would be if the continent were maintained in its elevated position, and the ocean floor maintained in its depressed position, by the rigidity of the earth.... It is certain that for the United States and adjacent regions, including oceans, the isostatic compensation is more than two-thirds complete, perhaps much more.'

Having found from a single seismogram a fairly accurate determination of the distance to the earthquake, the question naturally arises whether the same seismogram conveys any information as to the direction of the earthquake. If such were revealed by the record, then, knowing the distance, the position of the epicentre would become known.

It was at first believed that each horizontal pendulum gave one component of the earthquake wave, and hence the record of two pendulums mounted at right angles to each other would give a graphic solution of the parallelogram of forces, that is, the direction of the wave. However, Kovesligethy in his contribution 'Uber die Lesung seismischer Diagramme' in the first volume of the International Seismological Conference, has shown that this is not the case. He shows that all seismograms, of whatsoever nature, are dependent upon the seismic conditions of the surroundings. In consequence of the infinitely varied circumstances and conditions that lie in the path of the wave issuing from the hypocentre it is impossible for the rays of the spherical waves to continue in any given direction. To unravel all the vicissitudes that a wave suffers, due to the heterogeneous nature of the crust of the earth, the different rock formations of different degrees of elasticity and density, the dikes and faults encountered, is a problem that seems practically insoluble. What then does the seismogram show? It is evident that the seismograph records the differential movement of the pendulums and registering apparatus, which is dependent upon the immediate surroundings, *i.e.*, of the ground and building.

Examining our seismogram of the San Francisco earthquake with reference to the relative movements of the two horizontal pendulums, the one swinging in the plane of the meridian, the other in that of the prime vertical, we immediately notice that the former is considerably less affected than the latter, the ratio measured by the amplitudes which themselves are variable, being roughly as 1 to 2.

On first impulse, as San Francisco lies over 500 miles south of Ottawa, and is nearly five times as far west, one would be inclined to infer that the seismogram would give a record correspondingly, *i.e.*, that the pendulum moving north and south would be considerably less affected than the one moving east and west. To some extent this is the case too. However, when we consider that the seismic disturbance issues as spherical waves, and assuming the earth homogeneous, the direction of the ray will lie in the plane of the great circle passing through the two places. From the geographic coordinates of the two places we find that the azimuth of the ray at Ottawa is 274° 21', reckoning from north through east. That is, the ray arrives almost due east and west, in fact, a little north of west, and the wave-front practically in the plane of the meridian. The pendulum that lies in an east and west direction should therefore be hit 'end on' and remain quiescent, while the whole force of the wave should be manifested by the other pendulum, that is, if the impulse received by the pier were directly that of the spherical wave, its displacement would be in the above case confined to an east and west movement, and recorded only on one pendulum. This, however, is far from being the case, and we are to conclude from this particular case, as has been proved and shown in general before, that from a seismogram we cannot deduce the direction whence earthquake waves arrive.

The seismogram shows the transformed and modified wave movements, dependent upon the immediate surrounding conditions of ground, pier and adjustment of seismograph.

Formerly in dealing with earthquakes and making comparisons of the times recorded at different places it was assumed that the pulsations or vibrations emanated from a centre, or point, so to speak. This occasioned discrepancies in the deduced velocities, as well as, inversely, the deduced time of the earthquake if such was not directly observed. The trouble lay in the conception of the nature of the disturbance. Once we recognize that we have not to deal with a centre but with a disturbed surface the above difficulty disappears and fair accordance is obtained. Harboe has found that in the disturbed area the velocity of propagation of the earthquake waves is from 20-30 km. per minute, while at great distances it may attain a velocity of 3-13 km. per second, *i.e.*, from 2 to 8 miles per second. The velocity is dependent upon the modulus of elasticity and upon the specific gravity of the medium through which the wave passes. Numerous observations and records have shown that the velocity greatly increases with the distance from the immediately disturbed area, as pointed out by Schmidt.

The intensity of earthquakes was in the first place naturally expressed in terms of the resulting destructiveness or other outward phenomena. With the introduction of earthquake-measuring instruments the perception of seismic movements was extended beyond that directly observable. For making comparisons between different earthquakes, and for furnishing a scale to express the energy of the earth movement, Professor de Rossi of Rome in conjunction with Professor Forel of Geneva, devised the following scale as given by Major Dutton, which has been generally adopted:—

I. *Microseismic shock;* recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

II. *Extremely feeble shock;* recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. *Very feeble shock;* felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. *Feeble shock;* felt by persons in motion; disturbance of movable objects, doors, windows; cracking of ceilings.

V. *Shock of moderate intensity;* felt generally by everyone; disturbance, furniture, beds, &c., ringing of some bells.*

* House bells are evidently meant, such as were common before electric bells came into use.

VI. *Fairly strong shock;* general awakening of those asleep, general ringing of bells; oscillation of chandeliers; stopping of clocks; visible agitation of trees and shrubs; some startled persons leave their dwellings.

VII. *Strong shock;* overthrow of movable objects, fall of plaster; ringing of church bells; general panic; without damage to buildings.

VIII. *Very strong shock;* fall of chimneys, cracks in the walls of buildings.

IX. *Extremely strong shock;* partial or total destruction of some buildings.

X. *Shock of extreme intensity;* great disaster, ruins, disturbance of the strata, fissures in the ground, rock-falls from mountains.

In a scale like the above there is necessarily a certain amount of vagueness and want of precision in expressing the energy involved to produce a certain intensity, not to mention the varying sensibilities of different persons experiencing the phenomenon, and estimating the intensity accordingly, or of the varying strength of structures and building material in different countries.

Let us suppose a seismic disturbance to emanate from a point within the crust of the earth, and be propagated by spherical waves through a homogeneous or isotropic medium. Let the amplitude of a given wave-front of radius r, be A, and at the distance r' be A′. Now if we consider a thin shell of radius r, and thickness x, the energy due to the waves contained in this shell is proportional to the volume of the shell and to the square of the amplitude. We have thus:

$$E = 4\pi\, r^2\, x.\, A^2\, K, \text{ where K is a constant.}$$

If there is no dissipation of energy in the form of heat or otherwise, when this same energy is transmitted to a similar shell of radius r', it will be expressed by $E = 4\pi.\, r'^2\, x,\, A'^2\, K.$

Equating these two expressions we have

$$\frac{A}{A'} \quad \frac{r'}{r}$$

From which we see that the amplitude decreases directly as the radius or distance increases. The intensity of the wave motion being proportional to the square of the amplitude, it follows that the intensity decreases inversely as the square of the distance from the centre of disturbance. It follows that just as there are so many more particles in the larger shell than in the smaller, in that same ratio the energy of each particle in the former is less than that in the latter, the total energy being the same.

In 1888 Prof. Mendenhall, discussing intensity of earthquakes, gave mathematical expression thereto, and hence precision to the concept. He writes: 'It has long been customary to speak of the intensity of an earthquake without any special effort to give the word an exact meaning. Generally it is applied to the destructiveness of the disturbance on the earth's surface, and sometimes to the magnitude of the subterranean cause of the same. But modern seismology proposes to measure the intensity of an earthquake, and to express its value numerically. It is worth while, therefore, to inquire in what sense the term may be used with precision and what may be expected as its mathematical equivalent. Evidently it may mean, and in fact it has been made by different writers to mean, the measure of the surface of destruction, the energy per unit area of wave-front; the rate at which energy is transmitted across unit area of a plane parallel to the wave-front; and the total energy expended in the production of the original disturbance.'

In dealing with the propagation of energy by spherical waves, we consider the vibration of each particle to be in the nature of simple harmonic motion. Using the above symbol for amplitude, and t for the period $v = \frac{2\pi a}{t}$, $v^2 = \frac{4\pi^2 a^2}{t^2}$, and f the acceleration $= \frac{v^2}{a} = \frac{4\pi^2 a}{t^2}$

From the record or seismogram the numerical values of a and t can be obtained, and hence the maximum acceleration found. From a series of records of earthquakes

in Japan, Professor Omori has computed the respective accelerations. Knowing the intensity as expressed by the Rossi-Forel scale for each quake, he has prepared an absolute intensity scale for shocks varying from strong to destructive, that is, from VI. to X. of the former scale. His scale of I. to VII. corresponds to maximum accelerations of 300 mm. per second per second to 4,000 mm. and upwards.

In Omori's scale the maximum acceleration alone is considered, the element of time during which the acceleration acts being neglected.

An expression for intensity may be derived in the following manner. We have the general expression for energy $E = \frac{1}{2} mv^2$.

If we let V = speed of wave transmission, d = density of the medium, T = time during which whole waves are passing through unit surface of the wave-front

then $m = d\,VT$, and as $v^2 = \dfrac{4\pi^2 a^2}{t^2}$

therefore

$$E = \frac{2\pi^2 a^2 d\,V\,T}{t^2}$$

Hence the intensity or rate at which energy is transmitted across unit area of plane parallel to wave-front in unit time

is $I = \dfrac{2\pi^2 a^2 d\,V}{t^2}$

The seismogram furnishes the values of a and t, while d is approximately known as well as V.

It must be remembered that the record is of the behaviour of the earth particles immediately surrounding the pier and of the pier. When we come to apply the same to the determination of the energy involved or work consumed in generating waves in a given mass within the earth, we enter upon somewhat uncertain ground, not knowing what changes the movement of earth particles may suffer at different depths. 'We do not know the volume of earth that is in motion at the same instant, and must conclude, with the author of this method of analysis, that until more reliable data have been furnished, the results obtained by it can only be crude approximations.'

Regarding the depths of the earthquakes or hypocentre, if we consider the disturbance as emanating from a point, which can only be a theoretical consideration, very little is accurately known. Mallet in 1862, believed to be able to deduce the depth from the directions of cracks in buildings within the epicentral area. He assumed the earthquake wave to be propagated equally in all directions and that cracks themselves were in a direction perpendicular to the line of impulse. The intersection of the direction of these impulses obtained at various places would locate the origin, and from its position the depth would readily follow. As the assumptions are now known not to be consistent with facts, Mallet's method is no longer used. I may mention here that the number of cracks examined by me in the area extending from Napa, San Francisco, San José to Palo Alto, presented such a medley of directions that it was utterly impossible therefrom to determine by the above method the position or depth of the hypocentre.

Theoretically the problem does not appear so difficult. It may be stated in this manner: A shock takes place, its occurrence is recorded accurately at various places,—determine the position of the origin of the shock. On these lines Seebach attempted a solution in 1873. Dutton's method is to determine the position from the intensity curve. This curve is based on the general law, that radiant or wave energy is inversely proportional to the square of the distance from the origin. With reference to the recording of time,—it depends upon the delicacy and nature of the instrument or otherwise for its accuracy. Again, the earth not being homogeneous the velocity and propagation is not the same throughout the disturbed area, so that deductions based thereon can give only approximate values of the actual facts. Dutton concludes: 'That all earthquakes hitherto observed and recognized have their origins at very small depths as compared with the length of the earth's radius. All of them are only skin-deep. It is

practically certain that none of them start from so great a depth as thirty miles. It is highly probable that none of them start from a depth so great as twenty miles.'

With the multiplication and unification of instruments over the earth this interesting problem will undoubtedly yield up its solution.

The first earthquake recorded after the installation of the instrument in the beginning of January was on the 25th of the same month. The preliminary tremors arrived at 3–47–00 P.M. standard time 75° meridian; the maximum disturbance at 3–52–00 and the last phase or end of quake at 3–59–00.

This earthquake appears to correspond to the one reported in the daily papers as having taken place at 1.30 P.M. (Mountain time is 2 hours slow on above standard time), and which shook the section of the country lying between Gallup, New Mexico and Seligman, Arizona. Allowing five minutes for the transmission of the preliminary tremors, there appears to be a discrepancy of about 12 minutes in the agreement with the press despatch. Furthermore, the difference in time between the preliminary tremor and the maximum is less on the seismogram, that is to be expected for the distance, say of 1,800 miles.

On the seismogram of the above quake, the amplitudes of the two pendulums are about the same, but the north-south component (recorded by the pendulum pointing east and west), shows a decided earlier arrival of the preliminary tremors than the east-west component by nearly half a minute. The second phase of the preliminary tremors, which are generally shown, is not very apparent on the seismogram.

The same quake was recorded at the Cheltenham Magnetic Observatory, giving the same time for the beginning for the north-south component, but for the east-west component the time is a quarter of a minute earlier,* the reverse of above.

The principal record obtained so far is the one of the San Francisco earthquake of April 18th last. The times of the principal phases as taken from our seismogram are as follows:—

	North-South Component.			East-West Component.		
	h.	m.	s.	h.	m.	s.
Preliminary tremor. Phase I.	8	19	25	8	19	12
Preliminary tremor. Phase II.	8	24	48	8	24	40
Principal part.	8	31	20	8	30	32
Maximum amplitude at.	8	35	00	8	35	00
Average period of wave.	0	00	06·9	0	00	07·8
End.	11	48	00	12	48	00

The accompanying seismogram is from the original which is 90 cm., about a yard long. It will be noticed that during the maximum oscillations the vibrations were so wide and so rapid that the light spots from the mirrors were unable to impress themselves on the photographic paper, some in some instances are shown at the turning points of the to-and-fro motion, where small V-shaped impressions are seen.

Examining the record it will be seen that on the preceding day at $23^{h.}$ $50^{m.}$ G.M.T. ($15^{h.}$ $50^{m.}$ Pacific Standard), there was a tremor lasting about 18 minutes, possibly a premonition of the coming shock. After the main shock had occurred, the settling of the crust into a condition of repose was accompanied by two quakes, the times of the smaller one being

	h.	m.	s.	h.	m.	s.
Beginning.	2	22	00	2	21	30
Maximum.	2	28	00	2	27	40
End.	2	35	00	2	39	00
Maximum amplitude.		1 mm.			1·5 mm.	

and of the large one

	h.	m.	s.	h.	m.	s.
Beginning.	7	43	00	7	41	00
Maximum.	7	50	20	7	50	40
End.	8	25	15	8	32	00
Maximum amplitude.		5 mm.			6 mm.	

* Science, Vol. XXIII, p. 634.

All above times are in Eastern Standard time, being $5^{h.}$ slow on Greenwich mean time.

Severe as was the San Francisco earthquake, yet, as far as the actual movement of the earth's surface is concerned, neither it nor the one of Charleston in 1886 can be compared with the one of New Madrid in the Mississippi valley in 1811,* and which lasted for about a year, the destructive shock occurring on Dec. 16, 1811. The disturbed area lay between St. Louis and Memphis. 'Some of the earthquake rents were of great size, having widths of thirty feet or more, while some are reported as many as five miles in length. Others were circular in form, making basin-like depressions up to several hundred feet in diameter. Into some of these cracks rushed the waters from swamps and bayous, while elsewhere small streams or even rivers left their old beds and made new channels through the cracks. In one instance, a settler living on a neck of land lying within a great bend or ox-bow started at daybreak the morning after the quake to go to his well which the night before had been in his yard. But no well was there! Instead the river was at his door. Glancing across the water, however, the well could be seen on the farther side. During the night a crack had been formed between the house and the well and had been taken possession of by the waters, leaving both unharmed though on opposite sides of the stream.' Whole islands disappeared in the river. The ground rose and fell, as earth waves, like those upon the sea. The features for which the New Madrid earthquake is most renowned, however, are the swamps and lakes which resulted from the warping of the surface, due to the propinquity of the Mississippi. 'This earthquake is famous all over the world as one of the few instances of almost incessant shaking for a period of many months in a region remote from the seat of any volcanic action.'

The San Francisco earthquake of last April shows no such violence nor such permanent deformations of the surface of the earth as that of New Madrid in 1811. The presence of a large city within the seismic area accentuated or magnified the destructive effect of the earth-movement. When to this is added the greater devastation caused by fire consequent to the earthquake, the calamity of April 18 becomes memorable and historic. The pecuniary loss in San Francisco is estimated at about $300,000,000, whereof only $10,000,000 is attributable directly to wrecking by the quake. The lesson taught, and which is already well known in Japan, by this earthquake is that much, very much, can be done in structural designs to make buildings less susceptible to damage and destruction from seismic disturbances, and on the other hand prevent the spread of fire, when such originates through the collapse of buildings. In the burnt area there was especially one large building—notable by its solitariness—that arrested the attention of the writer as having escaped, simply through its provision against destruction by fire.

Nature is relentless towards sham and make-believe. With unerring certitude the earthquake shakes off the mask and discloses the true inwardness. The architect and builder have their work treated by an impartial hand. Buildings that present to the world a beautiful face, be it of cut stone, marble or brick, will have it rudely disfigured, unless it is one with the body. Inferior work and material will not escape the blind forces of nature.

After finishing my longitude work in Vancouver I returned to Ottawa via California in order to gain some personal knowledge of the earthquake, as I have charge of the Observatory seismograph. The earthquake area passed over by the writer extended from Mt. St. Helena at the northern end of the Napa valley to San Francisco, San José, Palo Alto, and Los Angeles.

Looking at a relief map of California one is struck by the great depression running longitudinally along the interior of the state, so that a comparatively small lowering of Golden Gate would turn the interior of California into a large sea, hundreds of miles long. Another striking feature is the general parallelism of the river systems together with their direction being approximately that of the coast line. It

* Pop. Science Monthly, Vol. LXIX, p. 76, M. L. Fuller.

would appear that such a disposition of the topographical features, that is, of valleys running N.W.—S.E., being at right angles to the gradient from the chain of mountains to the great depths of the adjoining ocean, lends itself particularly well for a line of rupture approximately in a N.W.—S.E. direction. The great fault or dislocation in California extends—as far as known—from Point Arenas in a straight line to Mount Pinos, 45 miles northwesterly of Los Angeles, a total distance of nearly 400 miles. It passes just outside of Golden Gate, the ocean-entrance to San Francisco; it then continues overland along the valley occupied by San Andreas and Crystal Springs lakes, passing to the west of Palo Alto, where is situate the Leland Stanford Jr. university, which suffered severely from the earthquake, and thence past San José, where considerable damage was done also, to Mount Pinos. Geologists familiar with the geological features, upon hearing or experiencing the quake, immediately concluded that along this line of weakness fresh evidences of sliding and movement would be shown. And so it turned out—although the displacements were not traceable as far south as Mount Pinos; on the other hand severe shocks were experienced north of Point Arenas and to the eastward of Cape Mendocino, showing apparently an extension of the fault about a hundred miles to the north, and almost wholly in the ocean. Along this fault then the strains set up within the earth by stresses of whatsoever nature, relieved themselves by sliding of the rock masses along the plane of fracture. From examination of the ground at various places it appears that there was a general relative displacement of the two sides in a N.W.—S.E. direction of about 10 feet, the western portion having a relative motion northward and the opposite side southward.

Where the displacement was as high as 20 ft., it was generally found to be due to the loose character of the soil. The difference in vertical distance of the dislocation was comparatively small, being about two feet.

It is not likely that along this plane of old rupture the fresh break of April 18, was absolutely simultaneous, some time would elapse in consummating the downfall, and subsequently some movements (minor shocks) would be manifested in settling down to a state of rest, even if not of perfect equilibrium.

Professor Milne writes me: 'The California earthquake may be represented by a displacement of 400 x 200 miles, through a distance of 4 to 10 feet. The depth to which the shattering extended may be 30 miles. More than 2 x 10^6 cubic miles of stuff gave the blow or blows which shook the world. This may be wrong but it is what I anticipate.'

Interesting as is an individual seismogram, its great value lies when it forms one of a world-encircling series, without which the study of earthquakes and the geophysics involved would be so restricted that many important questions would forever remain unsolved. For the present the writer must rely on the compilation of others. In an article by Dr. L. A. Bauer* the record for eleven stations is given; seven of which have seismographs only, three both seismograph and magnetograph, and one the magnetograph only. The part played by the magnetograph in an earthquake has not yet been satisfactorily explained. Whether the record given by it is simply a mechanical effect similar to that of the seismograph; or whether magnetic currents are set up by the earthquake and propagated through the earth, are questions awaiting solution. In the earthquake records by the magnetographs, the latter seem to show a 'selective' property, not known to the seismograph, inasmuch as the former will record some earthquakes and not others, without any apparent reason. The distances of the various stations vary from 1,500 to 6,000, miles in round numbers, and the inter-agreement of the deduced velocities of the seismic waves for the different phases is very satisfactory. The mean velocity of the pulsations passing along the chord, or more accurately along the brachystochronic line which is concave towards the surface, is 6·0 miles or 9·6 kilometres per second, the velocity increasing with the distance. This is obtained from the first phase of the preliminary tremors made by longitudinal

* Pop. Science, Vol. LXIX, p. 116.

waves. The transverse waves of the second phase of the preliminary tremors have a mean velocity of 3·5 miles or 5·6 km. per second. And, finally, the surface waves of the principal part of the seismogram show an average velocity of 2·4 miles or 3·8 km. per second. In these latter the deduced velocities are about the same for all the stations, not being affected by distance, as is the case with the first, which is as it should be. It is strange that the magnetograph of the four stations recorded only the surface waves of the San Francisco earthquake, and not the preliminary tremors as for previous quakes. The deduced velocities for the surface waves as deduced from the four magnetograms are identical with those of the corresponding seismogram for each station, so that in this instance at least, there can be no doubt but that the magnetograph recorded a mechanical and not a magnetic effect.

In closing this first brief report on earthquakes, questions that naturally present themselves to the public are: Are earthquakes liable to occur anywhere; and is the science of seismology sufficiently far enough advanced to be able to give a forecast, as with weather, what is going to happen?

To the first question a fairly definite answer can be given. Although earthquakes may occur in any part of the surface of the earth, for the simple reason that there is no part of the earth's crust that is wholly free from stress, and hence the tendency to relieve that stress, yet it has been found from observation that certain areas of the earth are more subject to seismic disturbances than others, due in a measure to the configuration or outline of the solid earth for any given area. Great elevations of lands adjoining great ocean depths are one of the factors conducive to frequency of quakes. That is, where there is a steep gradient from the land to the ocean bed, there we may especially look for such movement. Having this data to go upon, the next deduction therefrom is as to the locality in such an area where the disturbance will take place. The relief of the stress, the equalizing of the forces will necessarily take place along the weakest lines, at such parts that are least able to resist the thrust or tension forced upon them. These lines or planes of weakness are found in the faults and dislocations in the earth's surface, that is, in the geological formations. These ruptures were made in past geological eras or epochs, and now serve as planes of adjustment for any stresses set up within the earth, becoming thereby the epicentral region of earthquakes.

It may be said then with some degree of confidence that if there is a well-defined tectonic fault in a given area, and such area be visited by an earthquake, it will manifest itself most decidedly along such fault, there the earth movement will be the greatest and the destruction of life and property most calamitous in its vicinity.

Examining a geological map of Canada, it will be found that 'the great St. Lawrence and Champlain fault' is the most important one in the Dominion. Its course runs from Anticosti along the bed of the river to Quebec, from where it enters the south shore and in a gentle curve bends to Lake Champlain. This then appears to be our principal weak spot and if any adjustment of stresses and strains is to take place in Eastern Canada we may expect it to show itself most markedly along this line.

Professor Milne published a 'map of the world'* in which he indicates twelve earthquake districts together with the very large earthquakes which have originated from these districts since 1899. The district of the East Indian archipelago, that of Japan and that of the west coast of North America lead in frequency of earthquakes, the first having 41. Off the banks of Newfoundland is found a small district with three as the number of earthquakes. It would appear therefore that the probability of a severe earthquake visiting Canada is somewhat remote. It may be pointed out furthermore, that of all the great rivers of the earth, the St. Lawrence carries probably less detritus per cubic foot of water into the sea than any other. This means that there is less loading of the ocean bed, producing strains, than would otherwise be the case. That is, it is less of an earthquake factor relatively, than say, the Mississippi. This is due to two reasons. In the first place its drainage basin to the north for about 2,000 miles is composed mostly of archæan rocks whose denudation and erosion are small

* Geographical Journal, Jan., 1903.

compared with alluvium and rocks more easily disintegrated; the amount of the material carried away by water is smaller than it otherwise would be. In the second place, the material that is carried away is largely deposited in the long chain of lakes from Lake Superior eastward, so that by the time the waters reach the ocean they carry but a small proportion of the material that they in the first instance had borne from the surface of the earth. The St. Lawrence then is not so disturbing an element as its magnitude would appear to indicate.

As to prognostication: unfortunately, science has as yet not been able to make any forecast whatever. That earthquakes are the result of an adjustment, of an equalizing of stresses and strains within the earth, is known, but what forces are active, and in what degree each, in producing these stresses—that is the question upon which scientists are not yet agreed. The weather forecaster has the advantage of the telegraph line, by enabling him to know that 'something has begun to happen' far away, and from his meteorological experience can predict what will happen a day or few days afterwards. Without the telegraph, relying simply on such data as the rotation of the earth, the obliquity of the ecliptic, the eccentricity of the orbit, the amount of heat daily poured upon the earth, the circulation of the air, and similar material, the issuing of daily 'probabilities' would be another matter.

At present there are no instrumental means of any description available for heralding the arrival of an earthquake, nor is it probable that any such will ever be found. The outlook for forecasting does not look encouraging. Even when the generating forces of seismic disturbances have been definitely determined, their variability and periodicity tabulated, even then forecasts and predictions would probably only be possible in general terms, such as 'great or little seismic activity.'

Professor Milne has made a comparison* between the frequency of earthquakes and the change in direction of pole movement, *i.e.*, of displacement of the pole of the earth, as shown by the diagrams of Professor Albrecht, and found that there is a general agreement between frequency and rate of change. But the connection between two phenomena has not been established. If there is a connection it may be found that both are the result of a common cause. When that cause is found, as there are hopes of finding it, the forecasting of earthquakes will have made an important step towards realization.

Seismology has already done much in the study of geophysics and has aided in many ways the activities of man upon the earth, which in the long run must always be the justification of the pursuit of science. Although Canada is not seriously subject to earthquakes yet it is hoped that she will participate in appropriate measure with the other nations which have undertaken collectively a systematic study of the seismic conditions of the earth and the causes that lead thereto.

The evolution of earthquake instruments may be said to date from 1840. Amongst the old forms of instruments was a vessel filled with mercury and having eight or sixteen spouts or lips corresponding to the principal points of the compass. The vessel was completely filled with mercury, and under each lip was placed a cup to receive the mercury ejected by the shock. From the amount of mercury in any particular cup not only the direction of the impulse but also its magnitude or intensity were supposed to be indicated. However, this we know now not to be the case. Later we find the vertical pendulum introduced, registering its movements on a smoked surface, producing a tangled figure that no one has ever been able to read intelligently, for the motion of the pendulum itself after having been once set in motion is so involved in the motion of its support or point of suspension, that the seismic element is practically masked. The above primitive vertical pendulum was greatly improved by the labours of Ewing, Milne, Agamennone and others.

An inherent difficulty with all the various forms of vertical pendulums (also of horizontal ones) is that the earth vibrations are communicated to the point of support and in a greater or less degree affect the motion of the pendulum. If the difference of the periods of the earth vibration and of the pendulum be made as great as possible

* Nature, vol. 74, page 43.

then there will be less tendency of the pendulum to assume its own swing than would otherwise be the case. In the vertical pendulum the axis of rotation is horizontal. If this be inclined, and the pendulum remain at right angles thereto, the period will be increased in the ratio of the cosecant of the inclination, i, to the vertical, reaching the limit when the axis is vertical, the cosecant then is infinity, that is, the period is infinity, or the pendulum in equilibrium, motionless, in any position of azimuth.

For practical purposes a slight inclination to the vertical is given to the axis of rotation, sufficient to establish a definite zero position of the pendulum when at rest; the suspended pendulum is called a horizontal pendulum, as the bob swings practically in a horizontal plane.

A vertical pendulum and a horizontal pendulum, whose axis of rotation makes the angle, i, with the vertical, being at rest, if we give a slight tilt, a, to the respective planes containing the point of suspension and the centre of gravity, the vertical pendulum will be deflected a, while the horizontal pendulum will show a Cosec i. Hence the latter is far more sensitive and better adapted for the measurement of such deviations or deflections of the vertical. The end aimed at in earthquake instruments is in the first place to get an instrument to record only what is going on in the earth as communicated to it by the pier on which it rests; the instrument is to be an unbiased observer and recorder, devoid of personal idiosyncrasies. To attain this end wholly, is impossible. The 'steady point' (bob) of the pendulum is only partially steady or quiescent. The horizontal pendulum being delicately suspended, giving a long period and having a minimum of friction at its points of support, has in its bob or weight a steady point, a point such that when the frame of the instrument or pier upon which it rests suffers a displacement, this steady point will remain stationary, and its apparent motion by the shock is in reality the motion of the pier. When the pendulum is in equilibrium, then the centre of gravity of the system, which is practically that of the oscillating weight or bob, and the axis of rotation must lie in the same vertical plane. Furthermore, if in this plane a vertical be drawn through the centre of gravity and the axis of rotation produced till it intersects the above vertical, the distance from this point of intersection to the centre of gravity will be the length of the equivalent simple pendulum having the same period as the horizontal pendulum. From this relation it follows that the length of the equivalent simple pendulum varies directly as the perpendicular distance of the centre of gravity from the axis of rotation and directly as the cosecant of the angle of inclination, designated by i above.

When a series of impulses impinge upon the pier and set it vibrating, the horizontal pendulum will not remain for any length of time at rest, but will itself be set swinging. It will respond most readily to those vibrations which are commensurable with its own period. The displacement of the steady point in the first instances gives only the component of the disturbing force at right angles to the strut of the pendulum.

The Milne horizontal pendulum which is used at most of the British stations is always mounted in the meridian, that is, it records the east-west component of an impulse. Its boom, of aluminum, is about a metre long, and is provided at one end with a thin metal plate having a slit, beneath which in the registering box is another slit at right angles to the former, so that a beam of light, projected by a lamp and mirror on the slit appears as a bright dot on the photographic paper in the registering box. A time scale is provided by a small clock the long minute hand of which cuts off the light from part of the slit temporarily every hour. An hour is represented by two and a third inches, or six centimetres, on the record, or a minute in time by a millimetre.

Another common form of seismograph is that of Omori of the University of Tokio, and built by J. & A. Bosch of Strassburg. The boom, about three-quarters of a metre long, carries at its end a heavy weight, which is supported by wires from a massive casting a little over a metre in height. By a system of delicate levers the motion of the pendulum is magnified ten times, and the record is made by a fine steel

point on smoked paper wound around a large cylinder, revolving once in an hour. The paper is afterwards 'fixed' to secure a permanent record. By means of an electro-magnet in connection with a time circuit a record is made every minute on the paper, and thereby a time scale secured for the seismogram.

In the following description of the seismograph installed at the Observatory here, we have two distinct advantages respectively in the Milne and Omori seismographs combined, viz.: the photographic advantages of the Milne and the magnification advantages of the Omori and for the latter in a greater and more efficient manner.

The Bosch Seismograph.

The seismograph room is situate in the basement of the Observatory. The main room is 7·5 m. long and 1·7 m. wide, and is inclosed within solid brick walls 40 cm. thick. Entrance is gained at the east end from the hall through a lobby as shown on the accompanying diagram. The room is 2·6 m. high and a series of water and asbestos-covered hot-water pipes run along the ceiling. The pendulum pier is built of

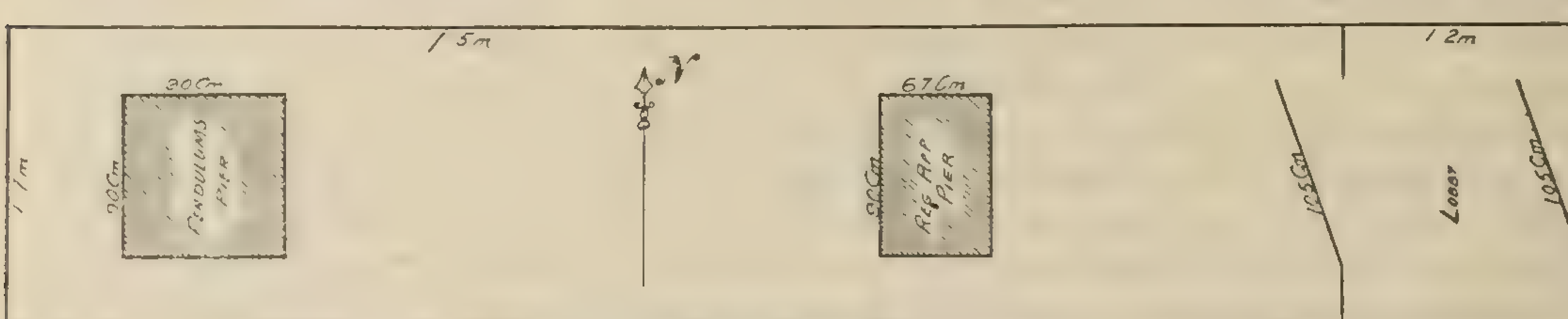


Fig. 4—Seismograph Room.

cement, it is 90 cm. square and extends beneath the cement floor which covers the whole of the basement, 77 cm. resting on boulder clay *in situ*. Beneath the cement floor the pier is protected from contact with the surrounding earth by a brick wall, 10 cm. thickness, leaving an air space between the wall and the pier of about 4 cm., this free space is decreased to about half a centimetre between the cement floor and pier. The pier is built N.-S., E.-W., and rises 77 cm. above the floor. The other pier for supporting the registering apparatus is also built of cement, but it rests directly on the cement floor. Its sides are 90 by 67 cm., and its top is 60 cm. above the floor. From centre to centre of the two piers is 4·1 m.

The lighting of the room is electric, 104 volt alternating current. A 16 c.p. light is suspended over the pendulum pier, and is seldom used. Centrally suspended in the room there is another 16 c.p. light, and over the registering apparatus there is a 16 c.p. ruby light. Of the light in the lamp for throwing a beam on the mirrors reference will be made later.

The following is a description of the Bosch photographic registering horizontal pendulum as illustrated by the three accompanying figures. It may be stated at the outset, that there are two identical instruments placed on the same pier, and at right angles to each other; the one in a north and south direction for giving the east-west component of any disturbance, and the other in an east and west direction for the north-south component.

The base of the apparatus is a heavy iron plate resting on three levelling screws. On the plate are mounted two brass columns, rigidly connected at the top. The pendulum consists essentially of a cylindrical mass or bob, figs. 1, 2, *a*, of 200 grammes, connected with the tubular rod, *l*, 4·6 cm. in length, which terminates in a conical agate cup, resting against the hardened steel point, *n*, which is firmly screwed to the support, *p*. The pendulum bob is supported by two fine wires, *b*, attached by eyes to the two studs projecting laterally from the bob. The position of the studs is such that there is little or no tendency for the agate cup to rise or fall at the steel point, *n*. The other ends of the wires are united in a stirrup, *c*, which is supported on a fine hardened steel point. The metallic framework connecting the two columns and upon which the stirrup rests has three adjusting screws, *d, e, f*. By means of, *d*, the pendulum may be raised or lowered; by means of, *e*, its azimuth is changed, *i.e.*, its point of rest; and

by, *f*, the inclination of the axis of rotation to the vertical may be changed. If the points of upper and lower support, at *c* and *n*, of the pendulum were in the same vertical line, then the pendulum would be in neutral equilibrium and the mass, *a*, would be at rest in any position. In order to give it stability, a slight inclination of the axis of rotation or motion of, *c*, in the direction of, *a*, is made. On the degree of inclination depends the sensitiveness of the pendulum. The distance from the centre of the mass, *a*, to the lower point of support is 6·2 cm., and from the latter to the upper point of support is 18 cm. The computed period of the pendulum swinging in a vertical plane is $^{s}\cdot26$, *i.e.*, the complete oscillation is $^{s}\cdot52$.

In order to modify the amplitudes and the free oscillations, there is attached to the mass, *a*, a light aluminum rod, *r*, terminating in a thin aluminum vane within the small air chamber *k*. The chamber is of brass, has a movable glass cover, and has a small horizontal slit for the admission and motion of the thin rod carrying the vane. The whole chamber has two rectangular motions backward-forward, upward-downward, by means of the screws, *g*, *h*, to adjust itself to the vane, and give it play which in the direction of the screws, *g*, *h*, is very limited within the chamber. The air within the chamber forms a cushion. To increase the 'damping,' there are two double walls in the chamber, and the inner ones may be made to approach each other by pushing in the studs, *s*, *s*. Unless the pendulum has a very long boom, the apparent displacement of the steady point is very minute and a magnification of the movement is necessary for purposes of record. When the magnification is effected by a system of long and short arm levers, as in some forms of seismographs, it is evident that the pendulum must do some work to overcome inertia and friction inherent in the recording apparatus, and thereby to a greater or less extent the sensitiveness of the pendulum is affected and destroyed. However, if the record is made photographically these disadvantages disappear. For this purpose there is mounted on each pendulum in the axis of rotation at the point, *n*, the small concave mirror, *m*, having a curvature of 4 metres or very nearly so. The recording apparatus contained within the oaken box, fig. 3, consists of a train of clockwork driven by a strong spring and regulated by a pair of governors similar to that of our (Fauth) chronograph. The brass drum carrying the photographic paper has a circumference of 90 cm., width 17 cm., and is provided at one edge with a projecting rim, perpendicular to its surface. This rim rests on two rollers, one of which is free to move, the other is driven by the clockwork, and the further necessary support for the drum is given by its axis projecting on one side and resting horizontally on two small loose wheels or discs in an upright. The brass axis is cut with a thread of 3 mm. pitch. The drum revolves by friction once in an hour so that each minute is 1·5 cm. long. By means of the threaded axis resting in the two small loose wheels spoken of, the drum moves laterally and the record is a helix with 3 mm. intervals.

A fresh sheet of paper is put on the drum daily.

The illumination for the mirrors is obtained from a lamp as shown in fig. 3. It is mounted on a frame which slides on the lower plate for proper focusing. Within the vertical tube there is an incandescent lamp 16 c.p., 104 volts, with single vertical filament. The ordinary commercial incandescent lamp with the twisted and looped filament is unsuitable as its image cannot be condensed to a point on the photographic paper by the cylindrical lens in front of the drum and shown by the slit in the box, fig. 3. The vertical tube revolves on an axis in the stand, it can be moved up and down, and clamped in any position. Underneath the vertical tube there is a screw for adjusting the verticality of the filament of the electric light.

The horizontal tube telescopes, and is provided at one end with an adjustable slit on which is thrown the image of the incandescent filament by means of an achromatic lens within the horizontal tube. Furthermore, beneath the slit is a small electro-magnet, the armature of which carries a small shutter to cover the slit. The electro-magnet is put into circuit with our standard mean time service and at every minute the armature is released for two seconds and hence cuts off the light passing through the slit for that time and the record shows broken lines at minute intervals accordingly.

In order to define the hour, the sixtieth minute is omitted, so that the line on the record from the 59th to the 1st minute of the following hour is continuous. The beam of light as it emerges from the slit is made just wide enough to cover the distance between the two mirrors of the pendulums. Each of these mirrors is adjustable on a vertical and on a horizontal axis so that the image may be thrown on the desired part of the cylindrical lens. The images are spaced about 7·5 cm. The cylindrical lens is 20 cm. long, its chord is 2·5 cm., and is 5 cm. from the drum; it is securely fastened to the inside of the box, behind the longitudinal opening seen, fig. 3, and covered by two brass plates separated 2½ mm. to admit of the condensed image. Twice the ratio of the distance of the steady point from the axis of rotation, to the distance of the latter from the drum where the image is, gives the magnification, which in this case is 120. That is, any movement of the pendulum is magnified 120 times on the record. Granting that the record may be read to a tenth of a millimetre, it would be equivalent to the measurement of the relative displacement of the steady point $\cdot 00083^{mm.}$ or the 1/30,000 of an inch, which is approximately the length of a light-wave at line A of the solar spectrum.

The thermometer seen in fig. 3, is hung up in the room, and is a 'wet and dry bulb' thermometer, for obtaining the hygrometric condition of the room from day to day.

During the winter months, when the ground was frozen, the seismograph room kept comparatively dry, but after the frost had disappeared the cement floor began to show signs of moisture. It was believed that by placing saucers of chloride of calcium about the room the moisture might be absorbed. Although within five or six days a half dozen saucers would be filled with water the relative humidity was not only not reduced but showed an increase from 70 in May to 85 in June, with a maximum of about 88 in July.

It was feared that this continued high degree of humidity would in time affect the efficiency of the seismograph, especially of the steel points supporting the pendulums. Although the basement and building are supposedly thoroughly drained, the other parts of the basement showing no moisture, undoubtedly due to the free circulation of air, which is not the case in the seismograph room, it was decided to lay two lines of tiles longitudinally through the seismograph room.

During the repairs all the instruments were dismounted on the eve of my departure, July 24, for the longitude work in Vancouver, referred to in the first part of the report, and were not mounted till my return in October. This accounts for the absence in our records of the great earthquake at Valparaiso on the evening of August 16.

At present (October) the room is quite dry, but the test of the efficiency of the additional tiling will not be apparent till next spring, as the present summer has been exceptionally dry, and the earth almost exhausted of all its moisture

DETERMINATION OF THE 141ST MERIDIAN.

During the season of 1905, the astronomic stations at Vancouver and Seattle were connected by the telegraphic determination of their difference of longitude; the observers were Mr. Edwin Smith, of the United States Coast and Geodetic Survey, and the writer.

Subsequently the longitude was carried by Mr. Smith and Mr. McGrath also of the U. S. Survey, by cable to Sitka and Valdez, and thence overland to Ft. Egbert or Eagle City, on the Yukon, about ten miles to the west of the 141st meridian.

It was arranged by the International Boundary Commissioners, Dr. W. F. King and Mr. O. H. Tittmann, that the determination of the meridian should be made from the determined positions of Vancouver and Egbert, Mr. Smith to occupy the latter station, Mr. F. A. McDiarmid of the Ottawa Observatory a station on or near the meridian, and the writer, Vancouver. Mr. McDiarmid and the writer were provided with practically identical astronomic outfits, Cooke transits Nos. 2 and 3, described in my report for Transpacific longitudes, while all three observers used the registering or

transit micrometer, whereby personal equation is eliminated, and the accuracy of the work increased, compared with the former method with transit key and noting the transit over a system of eleven threads.

The method and programme of work were similar to that described in my last year's report. Each observer obtained, if the night was clear, two independent time determinations each night, from two sets of 14 stars each, two thereof being polars and the other time stars. For each determination the instrument was used in positions clamp east and clamp west, seven stars in each position. The comparison of the clocks Boundary and Egbert, and Boundary and Vancouver, was made between the respective two time determinations so that the errors of the respective clocks were clinched, as it were, between the time determinations.

At Vancouver there is a permanent observatory for longitude work; at Egbert the pier of 1905 was occupied, while at Boundary Mr. McDiarmid erected a cement pier and hut. Boundary and Egbert being very near to each other, the telegraphic exchange of signals was readily accomplished. These signals were as heretofore 'arbitrary.' One observer would send twenty signals by means of a break-circuit telegraph key, then the other would send forty signals, and again the former twenty signals, so that the mean of the time of the signals of the first would be about the mean of the time of the other (40) signals, cutting out thereby differential rate of the clocks or chronometers, each observer having a break-circuit sidereal chronometer. Every night during the exchange of clock signals all the telegraph offices on the line were cut out, save those where there were repeaters.

The telegraph line from Vancouver to Boundary is composed of the following sections:—

Vancouver to Ashcroft	204	miles.
Ashcroft to Hazelton	587	"
Hazelton to Atlin	515	"
Atlin to Boundary	668	"
Vancouver to Boundary	1,974	"

In round numbers the distance is 2,000 miles. The iron wire is of No. 8 Birmingham gauge, weighing 360 pounds to the mile.

It may be observed that the above distances, supplied by Mr. Phelan, Superintendent of the Yukon Telegraph Line, were arrived at by 'wire mileage,' counting 3½ coils of wire to the mile. Repeaters were inserted at Vancouver, Ashcroft, Hazelton and Atlin. The electro-motive force employed was distributed as follows:—

Ashcroft, 60 gravity cells west, 132 cells north.
Hazelton, 115 gravity cells south, 85 cells north.
Atlin, 65 gravity cells south, 154 cells north.
Dawson, 150 gravity cells straight.
Egbert, 96 gravity cells straight.

At Vancouver storage cells were used.

The Vancouver-Boundary telegraph line passes nearly the whole of its course through a sparsely settled country, in fact, by far the greater part through a wilderness. Through the woods a fair 'right of way' is cleared and the wire is supported on trees from which the branches have been cut. Under these conditions, with the vicissitudes of wind and water and fire it was to be expected that interruptions in the telegraphic service would be not infrequent, but as it subsequently turned out, the service was better than anticipated, and here I wish to express my appreciation of the solicitous interest the superintendent, Mr. Phelan, took in the work, and furthered it by every means in his power. To Mr. Fletcher, too, chief operator at Vancouver for the Canadian Pacific Railway my thanks are due for his hearty co-operation this year as in former years.

On account of the high latitude of Boundary (64° 41′) and Egbert and the consequent long daylight, the longitude campaign was deferred to the latter part of the summer.

Attention having been called in the Astronomische Nachrichten No. 4101 to the probable occultation of 3 Geminorum by Jupiter on August 4, occurring shortly after noon, Greenwich mean time, it was suggested that I observe the phenomenon at Vancouver. Accordingly, I left for my destination on July 25, carrying with me besides the longitude outfit, the portable 4½″ equatorial, and also the Tesdorpf magnetic instruments. The transit was mounted in the observatory while the equatorial was mounted in the open air. The weather was very propitious and nightly time determinations were obtained until the night of August 3-4, when the sky was wholly overcast. The phenomenon was to occur or to begin about dawn. I remained up all night watching the sky to get a time set, but without avail. About dawn there came a slight rift in the clouds, and that rift disclosed Jupiter. Another moment and the equatorial was trained on the giant planet. Wires had been led from the observatory for the purpose of recording time on the chronograph. The four satellites were distinctly seen on one side of the planet and on the opposite side very near the upper edge shone brightly 3 Geminorum. I watched Jupiter slowly increasing its right ascension and approaching the star. How I wished as on similar occasions that there were no atmosphere, and that celestial bodies would not get 'glued' together, but instead each pursue its own course so that the phenomenon of occultation would be sudden and sharp as it theoretically is. Daylight was fast advancing, so were the clouds, and the air was becoming more and more tremulous, however a fairly good record of the time of ingress was obtained. When the time of egress came, clouds obscured the event.

We have—

	h.	m.	s.
Chronometer time of ingress	0	47	30
Chronometer correction	+0	00	43
Longitude Vancouver ($\phi = 49° 17'{\cdot}8$)	8	12	28
Greenwich sidereal time	9	00	41
Sidereal time G.M.N	8	48	34
Sidereal time after G.M.N	0	12	07
Greenwich mean time of event	0	12	05

Mr. McDiarmid reached Vancouver on the 3rd August, and left for Dawson on the 6th. A fortnight later he was installed at Boundary ready to observe. On the 22nd August we had our first exchange of clock signals. The weather or sky at night was very favourable at all three stations almost continuously, and the telegraph line as already stated gave less trouble than anticipated, so that by September 3 we had obtained seven differential longitude determinations between Boundary and Vancouver, for five of which each observer had obtained a full set of stars for the two independent time determinations, while for the other two nights, good time determinations were also obtained, but not with the full complement of stars. Similarly between Egbert and Boundary seven differential longitudes were obtained. At Vancouver the mean temperature during the observations was 60° F., the lowest being 56° F., while at Boundary the mean temperature was about 42° F., and the lowest just reached the freezing point. In order to assure as constant a temperature as possible the chronometers were kept in the observatory in wooden boxes, used for their transport, having 3-inch hair padding on the inside. Although the temperature of the observatory might vary within the building 20° F., in the 24 hours, that of the chronometer would be confined to about two degrees.

At Vancouver, where the pier was built years ago and is therefore practically settled, after the transit was mounted and adjusted in azimuth and levelled, the levelling screws were not touched thereafter, as it is preferable to take careful readings of the inclination of the axis than to attempt to level the instrument every night; for experience shows that there is a 'set' of the levelling screw after turning the same. Besides, as there is a small correction for inequality of pivots it would be impracticable to have the instrument level in both positions—clamps east and west.

The reduction of the observations, now in progress, will be made in the usual way. The three unknowns azimuth, collimation and clock error—involved in each observation equation will be deduced from each set of (14) observation equations by the method of least squares.

As already stated on the line between the Vancouver observatory and Boundary, there were four repeaters, *i.e.*, at each of the four stations there were two repeaters, one for transmitting automatically signals going north, and the other for signals going south. Although the repeaters, of the Weiny-Phillips type, were all alike, and their adjustments very similar, yet there was no absolute assurance that the transmission time of a signal going north say, was exactly the same as that of one going south, as they passed on their route through different repeaters. It was not found practicable to make the necessary changes for sending the signals in a given direction alternately through the two repeaters of each station. During the campaign the signals were sent through the repeaters as they were used in the ordinary commercial work. On the night of September 3, when the longitude work was completed it was intended to make the experiment of reversing the direction through the repeaters, but a vivid aurora borealis sprang up about Atlin, which interfered so materially with the electric circuit that the experiment had to be abandoned. However, on the following afternoon it was successfully carried out. The experiment consisted: (1) exchange of arbitrary signals as usual, 20, 40 and 20 signals; (2) repeaters reversed; (3) repeaters reversed, poles reversed; and (4) as usual, same as (1). The last, (4), condition assured, compared with the first, (1), the determinations of the differential rate of the chronometers for application to (2) and (3). It may be remarked that there was no change made in the adjustment of the points in the repeaters in the various experiments.

EXPERIMENT REGARDING TRANSMISSION TIME.

Vancouver—Boundary, Sept. 4, 1906.

(1) As in preceding longitude work. (2) Repeaters reversed. (3) Repeaters and poles reversed. (4) As in preceding longitude work, same as (1).

Condition.	Direction.	Vancouver middle time.			Difference of Chronometers.			Differential rate correction.	Difference of Chronometers for same epoch			Trans. time in both directions.
		h.	m.	s.	h.	m.	s.	s.	h.	m.	s.	s.
(1)	Western Signals	13	57	56	1	09	59·129	·000	1	09	59·129	·451
(1)	Eastern "	14	04	56	..	..	58·667	·011	..	..	58·678	
(2)	Eastern "	14	12	03	..	..	58·647	·022	..	..	58·669	·436
(2)	Western "	..	14	36	..	..	59·079	·026	..	..	59·105	
(3)	Western "	15	16	15	..	..	58·963	·123	..	..	59·086	·416
(3)	Eastern "	..	19	49	..	..	58·542	·128	..	..	58·670	
(4)	Eastern "	15	33	27	..	..	58·542	·153	..	..	58·695	·423
(4)	Western "	..	35	25	..	..	58·962	·156	..	..	59·118	

If d = absolute difference of the two chronometers at stations V, (eastern), and B (western), respectively.

t = transmission time with repeaters going west.

t' = transmission time with repeaters going east.

D_w = diff. of chronometers by western signals from B, and read on eastern, V, chronograph.

D_e = diff. of chronometers by eastern signals from V, and read on western, B, chronograph.

D'_w $_e$ similarly as above, but with repeaters reversed.

Then we have

$$D_w = d + t'$$
$$D_e = d - t$$
$$D_w - D_e = t + t' \qquad d = \frac{D_w + D_e}{2} - \left(\frac{t - t'}{2}\right)$$

Again
$$D'_w = d + t$$
$$D'_e = d - t'$$
$$D'_w - D'_e = t + t' \qquad d = \frac{D'_w + D'_e}{2} + \left(\frac{t - t'}{2}\right)$$

Hence $D_w - D_e = D'_w - D'_e = t + t'$, $d = \dfrac{D_w + D_e + D'_w + D'_e}{4}$, $t - t' = \dfrac{D'_w + D'_e - (D_w + D_e)}{2}$

or $t + t' = \dfrac{(D_w - D_e) + (D'_w + D'_e)}{2}$

Taking the mean of (1) and (4) = ^{s}·437, and the mean of (2) and (3) = ^{s}·426

we have $t + t'$ = ^{s}·4315

and $t - t'$ = ·0225

whence t = ·2270

t' = ·2045

That is apparently the transmission time going east, *i.e.*, going from Boundary to Vancouver is ^{s}·022 less than going in the opposite direction. We say apparently, for the inter-agreement of (1) with (4), (2) with (3), which should be identical, is of a magnitude of that quantity.

It is therefore not certain whether the difference of transmission times found for the two directions is apparent or real. In any case it is a very small quantity, the corrections being a hundredth of a second in time or less than seven feet at the Yukon boundary.

It is evident that by taking the mean of the mean differences of the chronometers found by the signals traversing first through one set of repeaters, and then through the other set, not only is the transmission time cut out, but also any difference in transmission time in going through the one set of repeaters compared with that going through the other set, or, which is the same thing, the difference of transmission time going in one direction and the other direction is eliminated.

While at Vancouver, the opportunity was embraced of obtaining a complete set of magnetic observations. The instrument used was that of Tesdorpf, the same that I used in Fiji, Australia and New Zealand.

The magnetic station was 48½ feet south of the observatory pier and 28½ feet west thereof, the geographical co-ordinates being

ϕ = 49° 17′·7

λ = 123° 07′·1

The declination was obtained from observations with the fibre declinometer, magnet 10, using the magnet in both positions, N up, and N down. As reference object, the finial of the steeple of the Catholic Indian Mission church across Burrard inlet in North Vancouver, was used. The azimuth of the latter was determined by observations on Polaris noting the time by a pocket sidereal chronometer, which was compared

with the box chronometer whose error was accurately known. The mean declination for August 21, 1906, at 2.50 P.M. was found to be 25° 04′·4 east.

Inclination was observed with both needles VII. and VI. The setting of the instrument in the magnetic meridian was readily obtained from the preceding declination observations. Each needle was observed in the usual position—circle west, face east, face west:—circle east, face east, face west. Then the polarity of the needle was changed by means of the two bar magnets, and another set—circle east, circle west was obtained. The inclinations as found by needle VII. on August 21, 1906, at 4.17 P.M., the mean of the time of beginning and end of observation, was 71° 40′·0.

On the following day at 5.05 P.M., with needle VI., the inclination was 71° 40′·2. The mean of the two needles is 71° 40′·1.

Deflection observations, with deflecting magnet 46, deflected magnet 10, were also made, besides oscillations observed of magnet 46. For noting time, Bond mean time chronometer 511 was used. It was compared for several days at frequent intervals with the Dent sidereal chronometer 48419, whose error was accurately known, and thereby the rate of the former determined.

The reduction of the oscillation and torsion observations have not yet been made and hence the value of the total force is not available at present.

I have the honour to be, sir,

Your obedient servant,

OTTO J. KLOTZ.

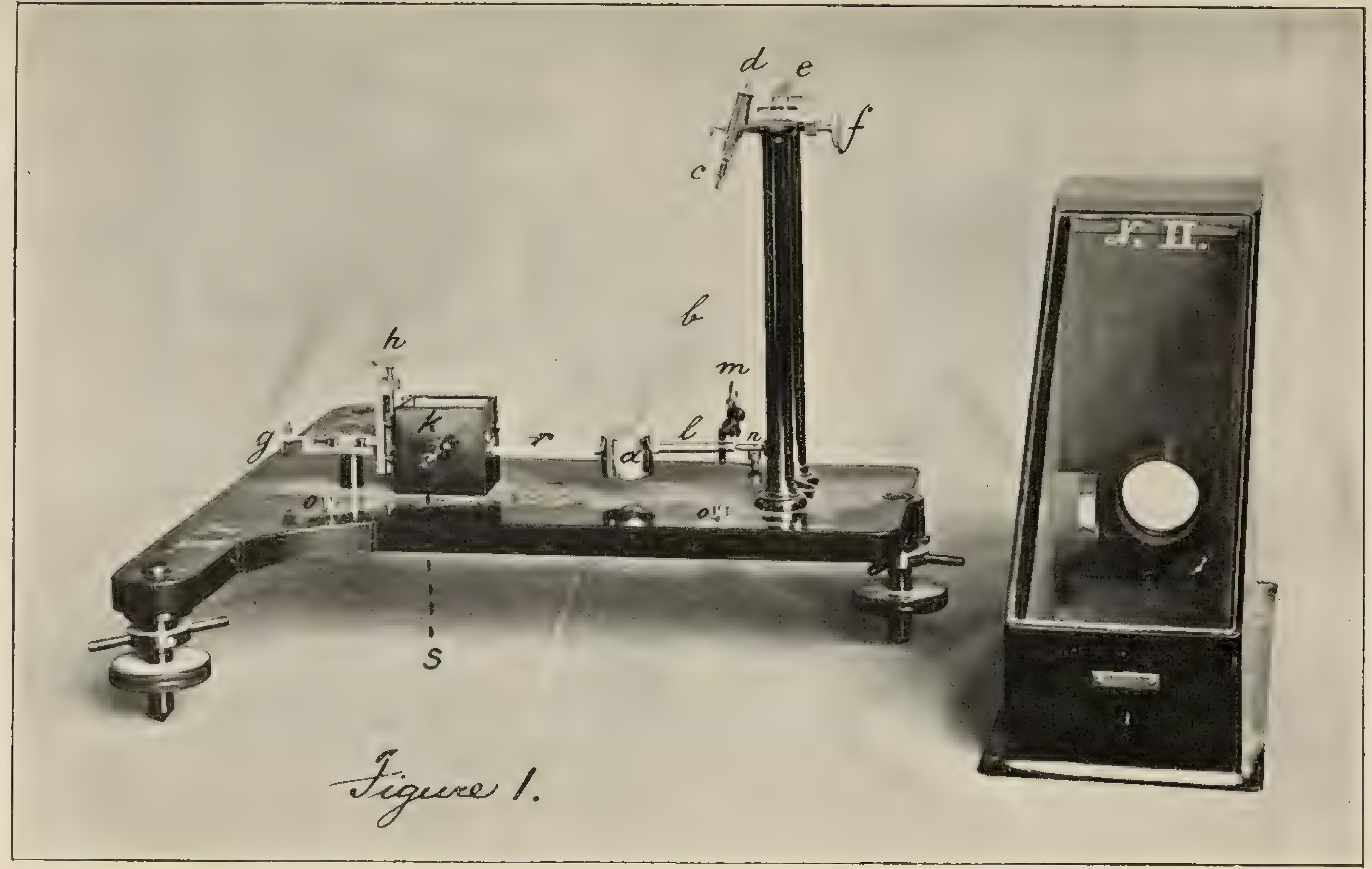


Fig. 1.—Bosch Seismograph.

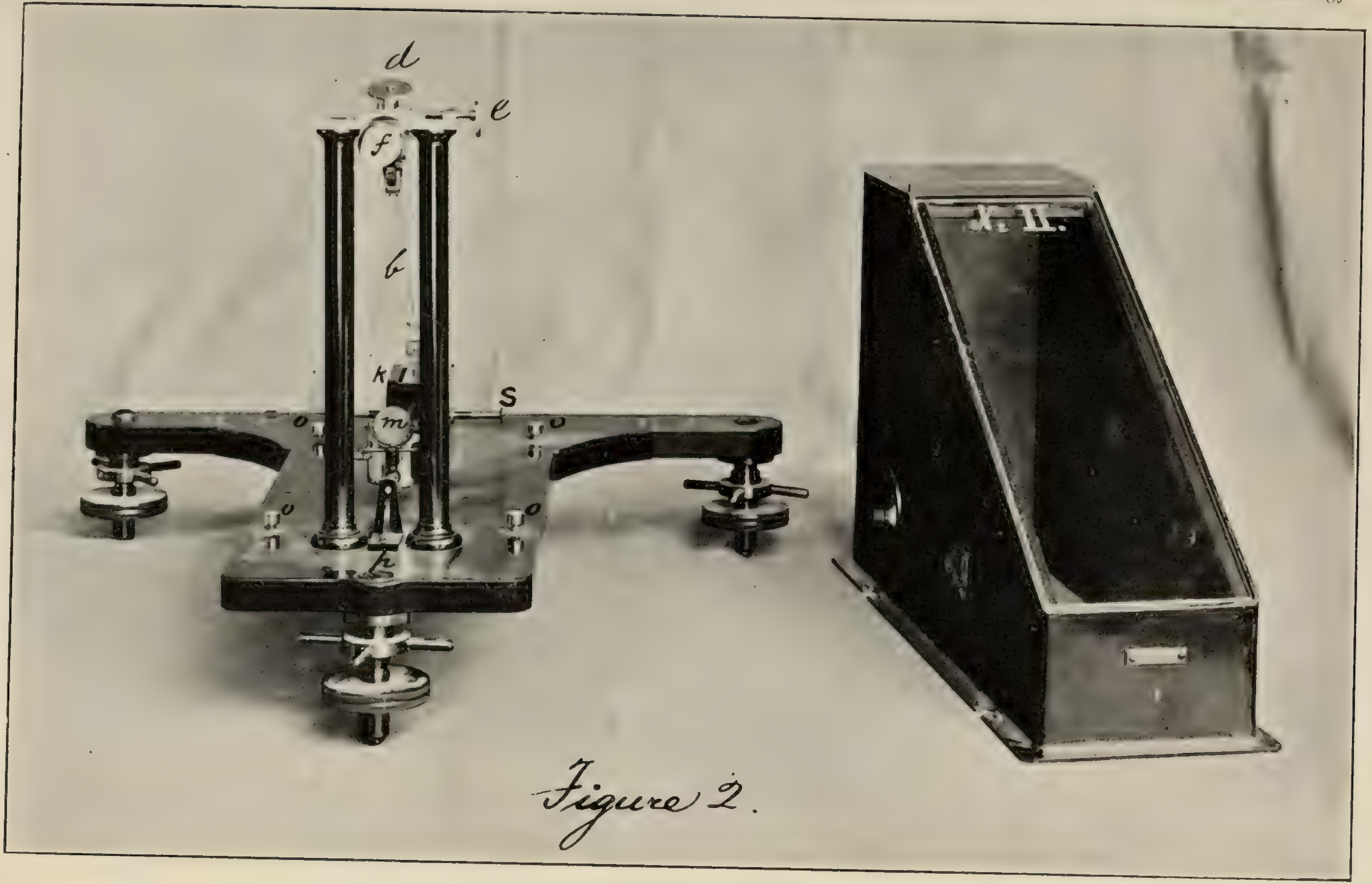


FIG. 2—BOSCH SEISMOGRAPH.

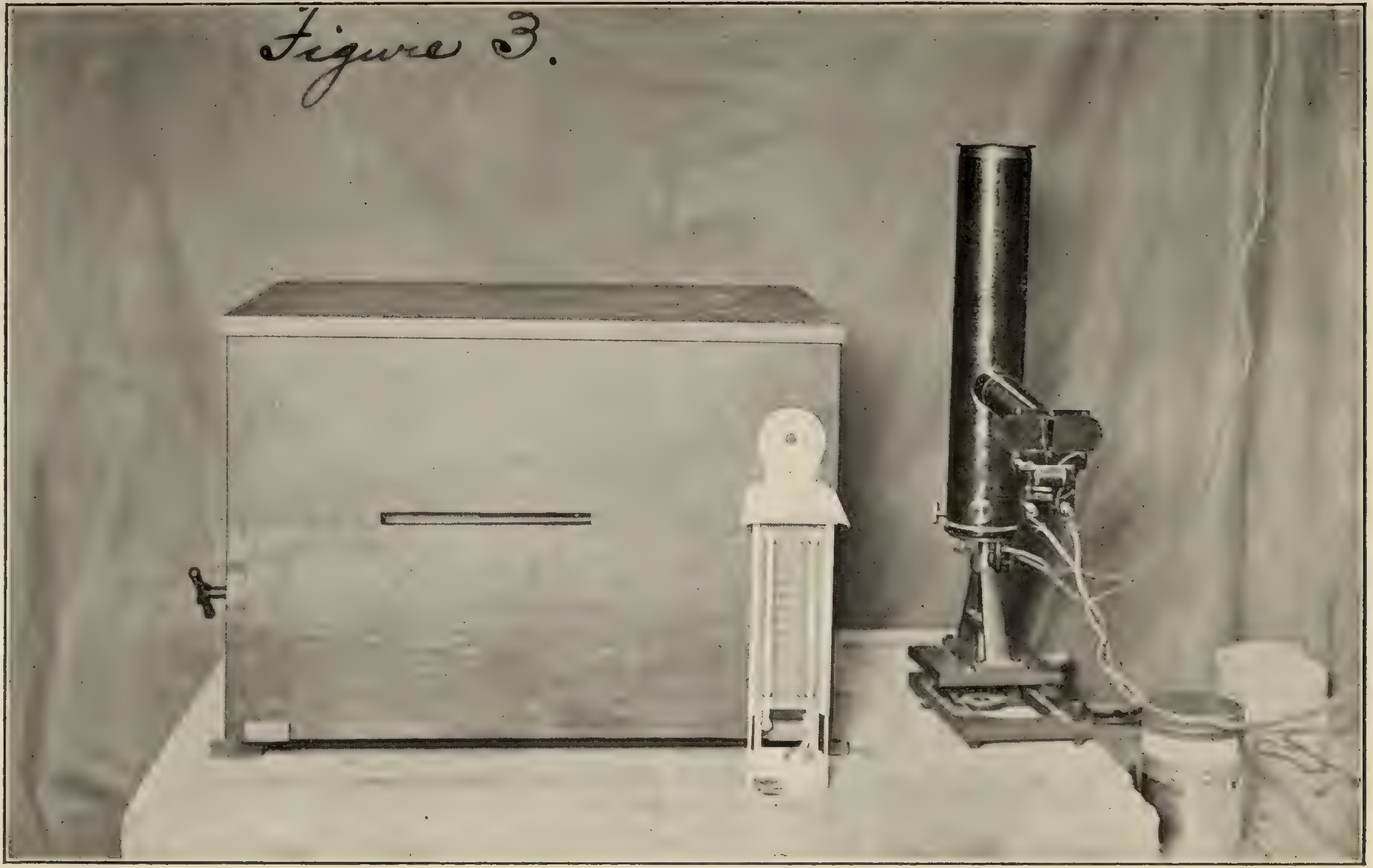


Fig. 3.—Registering Apparatus for Bosch Seismograph.

APPENDIX 2

REPORT OF THE CHIEF ASTRONOMER.

OBSERVATORY INSTRUMENTS AND ASTROPHYSICAL WORK

BY

J. S. PLASKETT, B.A.

CONTENTS.

ILLUSTRATIONS.

APPENDIX 2.

REPORT OF J. S. PLASKETT, ESQ., B.A., ON OBSERVATORY INSTRUMENTS AND ASTROPHYSICAL WORK.

OTTAWA, Ont., October 20, 1906.

W. F. KING, Esq., B.A., LL.D., &c.
Chief Astronomer,
Ottawa.

SIR,—I have the honour to report as follows upon the work organised and carried on by me during the past year.

Owing to its being the first year of the occupation of the Observatory, a great deal of time has necessarily been spent in erecting, adjusting and testing new instruments, and getting them into shape for regular work. Moreover, in the early part of the year, my time was entirely occupied with preparations for the Eclipse Expedition to Northwest river. After my return from the expedition, about September 10, 1905, the preparation of a report upon the expedition, and of a description of the observatory and instruments with the necessary photographs for illustrative purposes occupied considerable time. It was, hence, not until the middle of November, that I was able to devote much time to the astronomical work of the observatory. Since then my attention so far as regards astronomical work, has been chiefly directed to the measurement of the radial velocities of some of the brighter stars, to stellar, lunar and solar photography, and to the erection and adjustment of the concave grating spectroscope. The cataloguing and care of the field and observatory instruments and apparatus has occupied considerable time, as has also the fitting up of the workshop and the carrying on of numerous necessary and convenient pieces of work in it. The design of the house and tube for a coelostat reflecting telescope for solar research work, with the necessary mechanism for the adjustment of coelostat and secondary mirror to suit the varying declination of the sun, has also been completed. Further, a design for a combined single prism and three prism spectrograph of modern type for the accurate determination of velocities in the line of sight, which is to be constructed in our own workshop, has been practically completed.

The equatorial telescope has been in use practically every fine night since last November on Mondays, Wednesdays and Fridays by myself, in line of sight work and occasionally in stellar and lunar photography; on Tuesdays and Thursdays by Mr. Tobey, in photometric work; and on Saturday evenings for the use of visitors. This latter feature, which I have personally attended to except on two or three evenings when I was out of town, seems to be very popular, the average attendance of visitors since it was instituted having been greater than 50.

It has seemed preferable to consider the various matters that have occupied my attention under separate headings. They may be conveniently classified under the following subdivisions:—

Workshop.
Instruments.
Equatorial Telescope.
Stellar Camera.
Solar Camera.
Concave Grating Spectroscope.
Coelostat Telescope.
Stellar Spectroscopy.

WORKSHOP.

As described in last year's report, the workshop is equipped with a Rivett bench lathe, a 10-inch Hendey Norton toolmaker's lathe, and a Brown & Sharpe Universal milling machine No. 1½. Each machine is also well supplied with the necessary attachments and small tools for its efficient working. These machines were received in July, 1905, but nothing was done to put them into service until my return from the Eclipse Expedition in September last. As soon as possible after that date, I took steps to have the machines set up and placed in working order. The necessary shafting, hangers and pulleys were supplied by the Victoria Foundry, and were satisfactorily erected under my supervision by Mr. George Sparks, the engineer of the observatory. The whole equipment was ready for use by January 1, 1906, and since then has been very frequently used by Mr. R. M. Stewart and myself. The former has placed additional contacts in some of the electric clocks, has made an automatic thermostat for keeping the clock room at constant temperature and has executed numerous smaller repairs as well. Besides making small repairs and alterations to some of the field instruments, I have placed several trusses on the spectroscope for preventing flexure, remodelled the comparison apparatus, made new diaphragm for the slit and placed a double slide motion, adjustable from the eye end, on the correcting lens. The solar camera has been altered to adapt it to the new type of enlarging lens, and an electric synchronization has been placed on the driving clock of the telescope, while the driving worm has been re-cut to remove periodic errors. Many other small repairs and constructive details have also been attended to as the necessity arose, but these and the work mentioned above will be described each under its separate subdivision below.

Not much time was available for such work and the services of a competent mechanician were urgently required. Now that a capable man has been appointed, his services will be found invaluable to the observatory. With the addition of a small grinder to keep the tools and milling cutters sharp, work can be done with the machinery installed here which cannot be duplicated in Ottawa, and much time and expense will be thereby saved. There is sufficient work already in sight, including a new modern type spectrograph and the mechanism for the coelostat telescope and its spectroscopic adjuncts to keep the mechanician employed for at least two years, and this does not take into account the smaller details and repairs that will be continually needing attention.

INSTRUMENTS.

All the instruments used, both surveying instruments and observatory apparatus, are under my care. Those not in use are stored in the circular room directly over the entrance hall. Until the early part of the year they were temporarily placed in cupboards, &c., in the room, pending the completion and installation of the circular steel cases with glass doors which had been provided to contain them. After these had been erected, the instruments were classified as far as possible and arranged in the cases so as to keep the field instruments and others likely to be often required as accessible as possible. All particulars pertaining to each instrument, such as its location in the cases, when obtained, cost, by whom and when borrowed and returned, &c., are recorded in a convenient card catalogue. The proper looking after of the instruments takes considerable time and the question of repairs is a troublesome one. Some of the smaller repairs and alterations have been done by myself, but in the majority of cases the instruments have had to be sent away for the necessary repairs. Now that a mechanician has been appointed the trouble, delay and expense involved in this process will be to a great extent avoided, and there should be no difficulty in keeping the instruments in good shape.

THE EQUATORIAL TELESCOPE.

This instrument, which was fully illustrated and described in last year's report, has been employed during the past year chiefly in spectroscopic work, determinations

of the radial velocities of some of the brighter stars, but has also been used in photometric work by Mr. W. M. Tobey and as a guiding telescope for the stellar camera. An enlarging camera, which can be attached to the telescope, and which is intended for solar photography, has also been used in photographing the moon and some excellent lunar negatives obtained. Each of these will be treated in a subdivision by itself; it will be sufficient here to speak of the working of the telescope itself.

It has given excellent satisfaction on the whole and has answered admirably for the work done. One or two details, chiefly in the driving, have required attention in order to secure the most efficient results. It was early discovered, when the instrument was being adjusted, that the driving clock ran too fast, about two minutes to the hour, even when the governor was adjusted to its slowest rate. The proper remedy for this difficulty is to use longer governor arms, but as the obtaining of these arms would involve sending the present arms to the makers for some time, and hence stopping the use of the instrument during the interval, the difficulty was temporarily overcome by attaching a piece of lead to the lower part of each governor ball, thus lengthening the radius of gyration and slowing the clock. It was now found that, although the aggregate rate over a long interval, as compared with a standard clock, could be made nearly exact, the rate for a short time as observed when the telescope was pointed to a star, or when the star was brought on the slit of the spectroscope, was very irregular as shown by the image travelling back and forth over an angular distance of some 30 seconds of arc. This oscillation might be due to one or both of two causes—non-uniform motion of the governor; or periodic error in the clock train or driving mechanism.

Although some traces of periodicity were detected, they were so masked by other irregularities as not to be readily evident, and it therefore seemed probable that the trouble lay in the governor. It was noticed that it did not respond very quickly to any change in the driving force, and that the heights of the balls varied through a considerable distance while running. An examination showed that one of the screw heads was too long and rubbed against the governor arm, preventing its free movement. When this was filed off, there was some slight improvement in the driving, but it was still very irregular, and no efforts on my part met with much success in overcoming the difficulty. Such irregularities are very troublesome in investigations with the telescope, especially in photographic or spectroscopic work, as they materially increase the labour of guiding and diminish the efficiency and accuracy of the results.

Electric Control.

It seemed therefore worth while to attempt other means of getting rid of the difficulty, and an electric control seemed the most feasible. In consulting with Mr. R. M. Stewart, Superintendent of the Time Service, who has had considerable experience with electrically synchronized clocks, he suggested that the equatorial clock be synchronized with the sidereal clock, and that this be done by the pull of an electromagnet, actuated by the sidereal clock, on an armature attached to a wheel rotating in two seconds. This period is necessary on account of the arrangements of the contacts in the sidereal clock, which sent a current for one second every alternate second, that is to say the current is on for a second and then off for a second. I worked out the details of the mechanism, and, as there is no spindle revolving at the required rate, once in two seconds, it was necessary to introduce an auxiliary wheel for the purpose. The governor spindle revolves twice a second and the second spindle once in four seconds. A connection with the governor spindle was determined on as being more simple and direct and also on account of there being more room for the necessary mechanism. A reference to fig. 1 shows the arrangement of the scheme. It consists of a brass pinion, A, $1\frac{1}{2}$ inches in diameter, attached to the governor spindle, gearing into a brass wheel, B, 6 inches in diameter and $\frac{1}{4}$ inch thick. This wheel, which revolves on ball bearings, has mounted on its upper surface two sectors, C and D, each $\frac{1}{2}$ inch thick, $\frac{3}{4}$ inch wide and extending over 120° of the circumference. One of these sectors

is of brass, for balancing purposes, and the other of Swede's iron which is attracted by the electro-magnet, E, every alternate second. This electro-magnet, which is adjustable back and forth, has about 1,200 turns of No. 24 wire and exerts a strong pull on the iron armature when the current is flowing. The synchronizing current from the clock flows through the coils of the relay, F, while the electro-magnet, the points of the relay, and the storage battery of 5 cells form a second circuit, the conducting wires for both circuits coming up through the telescope column from the room below.

The governor is adjusted to gain a little on sidereal time, so that the original frictional contact will not come into action when the synchronization is working. After the governor has reached its full speed, the switch, G, connecting the battery and the electro-magnet is thrown in, and a current hence passes through the coils of the magnet for a second and is then interrupted for a second. As the wheel, B, rotates in two seconds, it will evidently turn 180° while, E, is a magnet. The armature, however, occupies 120° only, and if it is in synchronization, the wheel will be accelerated at the beginning and retarded an equal amount at the end of the magnetization of E. If, however, the mean position of the armature is behind the mean time of passage of the current, the acceleration will be greater than the retardation and vice versa. The tendency will therefore always be to bring the armature into step with the magnetization, and hence to keep the telescope clock at the same rate as the sidereal clock. Theoretically the mean time of magnetization and the central position of the armature should coincide, but the question is complicated, not only by the lag due to self induction and hysteresis, but also by the friction induced in the bearing by the magnetic pull, so that the armature is some 30° behind the magnetizing current. As first made, the bearing was furnished with balls at the lower end to take the thrust due to the weight of the wheel and armatures, but the friction induced on the plain bearing by the pull of the magnet on the armature was so great as to practically obliterate all synchronization, and it was necessary to make entirely new ball bearings for both ends. The whole mechanism, which is carried on a brass plate, H, firmly screwed to the top of the clock box, was made by myself in the workshop, and it completely overcomes the irregularities of the governor which now, when running, always remains in the same position, instead of moving up and down as formerly.

The Driving Worm.

The first effect noticed, when it was tested, was to exhibit very clearly a periodicity in the remaining irregularity which had now an angular amplitude of between 15 and 20 seconds of arc, about half its previous amount. This irregularity, whose period had previously been masked by the irregularity of the governor, had now a period of 4 minutes, which is the exact time occupied in one revolution of the driving worm, the connecting rod, and the last wheel in the train. The trouble must therefore be looked for in one or other of these parts, and the driving worm seemed the most likely place. The worm was dismounted from the telescope and placed between the lathe centres. It was at once noticed that the end of the worm shaft, which carried the bevel transmitting gear, was bent, but on straightening it, and replacing the worm there was not much improvement. It was therefore again taken out, put in the lathe and thoroughly tested. The hardened end of the shaft which received the thrust of the worm appeared to be true, and there only remained the worm itself. A careful test showed that it was not concentric with its shaft and journals, so that, even supposing the screw were correctly cut, its eccentricity with respect to the journals on which it revolves would cause it to mesh more deeply into the teeth of the worm wheel at one part of its revolution than another, and this defect would be quite sufficient to cause the observed irregularity.

The method employed to remedy the trouble was to make the shaft as straight as possible, so that the bearing parts ran true, or as nearly so as possible, when revolved between the lathe centres. The thread was then re-cut with the utmost care, using a very sharp tool and taking very light cuts, removing the least possible amount of

 FIG. 1.—Electrical Synchronization of Telescope Driving Clock. p. 46

metal consistent with accuracy. Finally after this was finished a very light cut was taken over the journals to ensure their being concentric with the thread. It was thought better to do this even at the cost of having them slightly loose in their bearings.

On testing it was found that the drift was now reduced to less than one-fourth of its original amount, being now only three or four seconds of arc, equivalent at the focus of the 15-inch objective to about 1/300 inch. This is probably as good as can be obtained without making an entirely new screw, and such an amount of drift is not objectionable for some purposes. For spectrographic work it is, on the contrary, an advantage to have the star move slowly along the slit, provided the amplitude of oscillation is not too great, as was originally the case. The length of slit used is about 1/100 inch, so the drift is about ⅓ this length, and it is easy to so divide this length and the required exposure as to get practically uniform exposure over the whole width of star spectrum.

Although considerable time was occupied in devising, constructing and adjusting the electrical synchronization, and in correcting the driving worm, I consider it time well spent as not only is the labour of guiding very much diminished, but the accuracy is increased and the exposure time correspondingly diminished. In following a star for photographic or spectroscopic purposes, only the small differential corrections for inexact adjustment of the instrument, and for change in refraction with varying altitude require attending to.

THE STELLAR CAMERA.

The objective of this camera is a photographic doublet of 8 inches aperture, and 40 inches focus made by Brashear. It was fully described in last year's report, and an example of the work done with it was there reproduced. It gives beautiful star images over a large field the extent of good definition being fully equal to, if not greater than in any other objectives of whose work I have seen reproductions. The camera is attached to the tube of the equatorial telescope which is used as the guiding telescope. This prevents its extended use as no other work can be done with the telescope while a star photograph is being made. However, last fall the camera was put in accurate focus, and some photographs in the Milky Way obtained. Recently the camera has been used by Mr. W. M. Tobey for photometric work. He has been testing it on some short period variable stars, the change in brightness being exhibited by a change in the diameter of the star image, according to a certain empirical relation. His work has not yet proceeded far enough to give any definite results. If some useful and continuous work could be found for this camera, it would seem desirable to detach it from the telescope and provide it with an equatorial mounting and a guiding telescope so that it may be used regularly without interfering with other work.

THE SOLAR CAMERA.

It had always been the intention to use the telescope for obtaining large scale photographs of the sun's surface to record the areas of spots, &c. As the diameter of the solar image in the focus of the objective is only about 2½ inches, some type of enlarging lens must be used to obtain the necessary size of image and as a negative lens requires less extension of the telescope, it was chosen for the purpose. The curves of this objective were computed by Hastings, and the lens itself, and the camera, which consisted of a conical tube screwing into the same flange as the eye end and spectroscope adapter, with rack and pinions for focussing and a simple slit shutter for the short exposures required, were made by Brashear. The lens and mounting were received shortly before starting on the Eclipse Expedition, and then there was only time for a short trial. Although the definition obtained was very poor, it was thought that further adjustment might improve matters.

As soon as possible after my return the lens was further tested, both visually and photographically, all possible adjustments were made, but no definition whatever could

be obtained. I had from the first been somewhat sceptical as to the possibility of obtaining a well-defined enlarged photographic image over a considerable angular field from a visual objective. When it is remembered that the photographic light, which extends between the wave lengths of λ 5000 and λ 3800 say, forms foci at different points along the axis, extending over a range of upwards of an inch beyond the visual focus of the telescope objective, and that the enlarging lens has to unite all this light into a focus at one plane not only along the axis, which would be feasible enough, but over an extended surface of about 10° angular aperture, it is evident that a two-lensed objective can scarcely fulfil these conditions. It seemed to me that there would be much greater hope of success if the enlarging lens were corrected for the visual part of the spectrum, the same as the objective of the telescope, if an orthochromatic plate sensitive to the visual light were used, and if the photographic light, which would give blurred images, were prevented from reaching the plate by an absorbing screen or filter. In correspondence with Brashear, it was learned that Hastings had misunderstood the requirements, and the original enlarging lens was only corrected for axial light, and was hence quite useless for solar photography. My idea in regard to a visually corrected enlarging lens was accepted, and a new lens was made for us by Brashear. It was received in April last, and owing to the fact that its focal length was slightly shorter, in order to obtain a larger solar image, the camera had to be modified to suit the new conditions, after a preliminary trial with temporary adjustments to determine the best position of lens and plate. The lens had to be placed lower down in the tube and the opening between lens and plate enlarged to admit the full beam. This trial showed that the definition was very much improved and the prospects of good results looked hopeful. However, an examination of the image through the shutter slit showed a marked deterioration, probably due partly to diffraction and partly to the position of the shutter which was about a quarter the distance between lens and plate away from the lens, and hence not near the place where the pencils were combined. Indeed with a negative enlarging lens the only real focus is on the plate and it therefore seemed necessary to use a shutter near the plate. A sliding metal shutter would be so heavy as to cause vibration and a Thornton-Pickard Focal Plane shutter, in which the moving part is a light roller blind having a narrow slit in it moving rapidly across the plate, was ordered. In order not to have lines across the negative parallel to the motion of the blind, the slit was to be faced with smooth and straight metal edges.

While waiting for this shutter the camera has been used in lunar photography, and a number of excellent negatives have been obtained. A reproduction of a print of one of these, exposed on June 1, 10h. for ten seconds is shown in fig. 2. An absorbing screen was made from two pieces of thin plate glass 8 inches by 10 inches in size, coated with gelatine and then stained in a solution of tartrazine, an orange-yellow dye very useful for yellow screens, to such a depth that the two combined absorbed all light of shorter wave length than λ 5000. These two plates are sealed together film to film with Canada balsam. This filter is placed as close to the plate as possible in order to avoid distortion of the image owing to deviations of the surfaces from accurate planes, for although they are a good quality of plate glass the surfaces are not optically worked. The plates used for the lunar photography were Cramer Instantaneous Isochromatic, and the exposure given varied from 5 to 20 seconds, depending on the age of the moon and the aperture of the telescope objective which was in some cases diaphragmed to 7½ and 10 inches. The aperture used for the negative of the reproduction was 10 inches. The rapid motion of the moon in right ascension and declination must necessarily have caused some drift of the image on the plate even with an exposure of 10 seconds only, and this will to some extent diminish the sharpness of the image. Owing, however, to the use of the screen which increases the exposure some five times, and to the relatively small angular aperture about f—80, a shorter exposure is not possible. However, very good definition has been obtained, and as soon as the shutter arrives the camera will be put to regular use in the photography of the solar surface.

5146 FIG. 2.—The Moon—June 1st, 15 h, G.M.T. Age 9 days. p. 48

THE CONCAVE GRATING SPECTROSCOPE.

This instrument, which was briefly described in the last report, has been set up and adjusted during the present year, and some photographs of the solar spectrum obtained. The grating is of 4 inches aperture, ruling about 3½ inches long, 2 inches wide, containing 15,000 lines to the inch, and the whole grating about 50,000 lines, hence, giving a resolving power of 50,000 in the 1st order spectrum, 100,000 in the 2nd and so on. The radius of curvature of the surface is 10 ft. The mounting, of the Rowland type, consists of two rails at right angles, with the slit at their intersection. Two carriages, one carrying the grating, and the other the eyepiece or camera connected by a tubular arm, the same length as the radius of curvature 10 ft. roll, one on each of the rails. The advantage of this type of mounting is that, when once adjusted, different parts of the same spectrum or spectra of different orders are all in exact focus, and are brought into the field by simply rolling the carriages along the rails. The mounting was made in a very satisfactory manner by Brashear, and, although the adjustment of this type of spectroscope is rather a troublesome matter, the workmanship is such as to facilitate the various adjustments as far as possible. The adjustments necessary in this case are as follows:—1. The rails, which are steel T-beams with the stem of the T upwards and planed true and smooth, must be exactly at right angles to each other. 2. The connecting tube must be pivoted to each carriage vertically over the rail, and its length between pivots must be exactly the same as the radius of curvature of the grating. 3. The grating and camera must have the centres of their effective surfaces directly above the pivots connecting tube and carriages. 4. The axis of the grating must pass through the centre of field of the camera or eyepiece, and, as a consequence of (2), the centre of curvature must coincide with the centre of the focal plane of camera and eyepiece. 5. The slit must be placed exactly above the intersection of the rails. 6. The ruling of the grating and the slit jaws must be parallel to each other.

As each one of these adjustments is interrelated with the others, and as the final test is the definition of the spectrum, the whole adjustment is a question of continuous and successive changes and tests. In the first place all the adjustments were made mechanically as closely as possible, the rails, for instance, being placed very nearly at right angles by measurement of the sides and calculation of the corresponding hypothenuse of a right angled triangle. The definition was then tested and slight changes made in the adjustments until, with the movement of the carriages along the rails, the spectra remained in accurate focus.

The grating is mounted in the room directly below the equatorial room at the midway floor, and is so placed that the rail on which the grating carriage rolls, points towards the south window of the room. Outside this window a small platform is placed to receive the heliostat, when sunlight is required, and the light from its mirror is reflected through an opening in the shutter to a quartz condensing lens, which forms an image of the sun on the slit. Thence the light passes to the grating and is diffracted back to the camera. All the windows of the room are closed by light-tight shutters to prevent extraneous light from reaching and fogging the plate. A small dark chamber parallel to the rail carrying the camera contains an arc lamp for forming arc spectra of the metals. The light issues from this chamber at right angles to the direction of the sunlight and can be reflected into the slit by a plane mirror at 45°. Hence, when any wave length determinations are required as will sometimes be the case in stellar spectroscopic work either the light from the sun or that from incandescent terrestrial substances can be thrown on the slit.

COELOSTAT TELESCOPE.

As mentioned in the last report, it was proposed to use the coelostat obtained for the Eclipse Expedition as the nucleus of a horizontal reflecting telescope for solar research work, and considerable time has been spent in designing the most suitable

arrangement for this telescope. It is proposed to use the room in the basement under the time room as the solar research laboratory, and an image of the sun is to be formed within this room or in a small annex to the north by a concave mirror of about 80 ft. focus and 18 inches aperture. The coelostat is to be placed in a house about 70 ft. north of this laboratory, which is arranged to roll back on rails to uncover the mirror to the sun, and the light from the coelostat mirror is to be reflected south to a secondary adjustable plane mirror, whose position can be changed to allow for the varying declinations of the sun, and thence north to the concave mirror. The dimensions and general design of the necessary shelters for the coelostat and the secondary and concave mirrors and for the ventilated tube to conduct the light from the concave mirror to the laboratory have been worked out, after consultation with those who have had experience with similar instruments, and the Department of Public Works are now engaged in making the necessary detail drawings. It is expected that these shelters will be constructed this season, and as the two mirrors have been ordered and will be here in good time, it is hoped that the installation will soon be ready for work. Full detail drawings of the necessary adjusting mechanism for the coelostat and the secondary and concave mirrors have also been completed, and this work can be started at any time so as to be ready as soon as the buildings. It is proposed to begin with the photographic study of the spectra of sun spots, and with the spectrographic determination of the period of solar rotation in co-operation with others engaged in the same work, but the programme will be expanded as we develop to embrace other lines of research on the sun which may be helpful in elucidating some of the intricate problems, connecting the constitution of the sun and the periodic changes occurring on its surface, with climatic and meteorological conditions on the earth.

STELLAR SPECTROSCOPE.

The spectroscope which is of the universal type, arranged to be used visually or photographically with the following dispersing media:—1. A light flint prism. 2. A dense flint prism. 3. A train of three dense flint prisms. 4. A plane grating, was made by Brashear and was fully described and illustrated in last year's report. The principal optical data are repeated here for convenience. Collimator of 15 inches focus and 1¼ inches clear aperture, but as, when used with the equatorial, the effective aperture is only about an inch, it was diaphragmed to that size. Camera 1¼ inches aperture and 15 inches focus. Resolving power with the train of three prisms about 40,000, and linear dispersion at $H\gamma$ about 19 tenth-metres to the millimetre. A photograph of the instrument as modified for radial velocity work is reproduced in fig. 3.

Except for its use with the single dense flint prism in tests of the colour sensitiveness of photographic plates for photography of the Corona, described in last year's report, the instrument has been used almost entirely with the train of three prisms, mostly for measurements of the velocities of some of the brighter stars in the line of sight. The train of three prisms has also been used to photograph the green, yellow, and red parts of the spectrum of some third type stars, using for this purpose plates bathed in Pinachrom. These were found very suitable, giving a spectrum practically uniform in intensity between λ 4000 and λ 6000, and also being very sensitive to the longer wave lengths. The red end of α Orionis and α Taurus was photographed in much less time on Pinachrom bathed plates than the blue end of the same stars could be photographed on the fastest ordinary plates.

The universal type of spectroscope, although useful for a great variety of work, is not suited for determinations of radial velocity, as its universal character prevents the thoroughly rigid construction so necessary to prevent the displacements of the lines likely to occur during a long exposure. What is required for thoroughly accurate work of this nature is a spectrograph built from beginning to end with that one object in view, the greatest possible rigidity of construction and consequent invariability of the relative positions of the parts during the change of position involved during a

long exposure. This of course, is not the only point that requires attention in designing a spectrograph, but it is a very important one, though displacements due to temperature changes also require careful consideration. Although some statements in regard to the difficulty of obtaining good results with the universal type of instrument had been published, I had not fully realized the difficulties involved. The adapter and correcting lens were not received until the spring of last year, and press of work in preparation for the Eclipse Expedition, and other urgent duties with very unfavourable weather after my return, prevented any extended trial until November, 1905. A few negatives then served to show that, with the instrument in its original form, first-class results could hardly be expected, and, until a new spectrograph built solely for radial velocity work could be obtained, I determined to make the instrument as serviceable as possible. A series of very thorough tests of its performance under varying conditions was made to determine the weak parts, and these were improved or removed as soon as discovered. A short description of these tests and of the modifications and changes necessary in the instrument will now be given as it may be useful to others engaged in the same work and is necessary to make what follows complete.

Focus of Collimator.

The first adjustment required, the focussing of collimator and camera, is a very important one, especially that of the camera as will be seen later. Three methods of determining the collimator focus were employed, Schuster's, Lippmann's and Newall's, with fairly accordant results. Schuster's method consists in fixing the observing telescope at a greater deviation than the minimum, and so changing the focus of camera and collimator, that any line will be in sharp focus in the two positions of the prism which bring the line into the field. Both the dense single prism and prism train were used in this method, giving the same value, about 15·6, on the index and scale of the collimator. This method seems to be sensitive as successive values of the reading differ from one another by about 0·2$^{mm.}$

Lippmann's method of focussing which depends upon the lateral displacement of a pencil of light by a plane parallel plate placed obliquely was also tried. A Lippmann focussing device, which consists of two plates each about $\frac{1}{4}$-inch thick, $\frac{1}{2}$-inch wide, and about 3 inches long placed on edge over one another, crossing centrally at right angles, was inserted in the beam from the collimator, displacing one half the beam in one direction, and the other half in the other. When the beam is parallel, these displaced pencils will all be united at the camera or telescope focus, but if not parallel, they will form two foci and the lines will be double. I could not, however, get such accurate results by this method as Schuster's as the position where the lines were single could not be determined closer than about a millimetre.

Newall's method, described in *Monthly Notices* 57, p. 572, was also tried, but this, in my opinion, is more applicable to the determination of the exact camera focus. The principle of the method depends upon the exact combination at the focal plane, of all the pencils of light passing through the objective. At points within and without the focus, however, a pencil from one side of the objective will form an image of a spectral line on the same or opposite sides, respectively, of the image of a spectral line given by a pencil from the other side of the objective. If two spectra can be made side by side, one spectrum being produced by light passing through one side of the objective, and the other spectrum from the other side of the objective, then, if the plate be at the exact focus, the lines of these two spectra will coincide in position or form continuous lines, while, if the plate be within or without the focus, the lines will be displaced relatively to each other, and the magnitude of this displacement gives a measure of the distance of the plate from the true focus. As applied to the determination of collimator focus, however, this method does not give definite enough results as a deviation from the true collimator focus of a millimetre on either side could be so compensated by exactly focussing the camera as not to be evident by any displacement of the lines.

Wadsworth says in the *Astrophysical Journal,* vol. XVII. p. 17, that accuracy in focussing the collimator is unimportant compared to camera focus. This is exactly what my experiments have shown, and was the conclusion I had reached before I noticed that portion of his article. Eight series of spectra, made in the manner described above, were taken of the iron spark, one series for each half-millimetre setting of the collimator lens between 14·0 and 17·5 inclusive, the setting by Schuster's method being 15·6. In each series six photographs were taken, using camera settings $\frac{1}{10}$ millimetre apart, the best camera focus being about the middle of the range. In each series of six, the spectrum was selected whose lines were continuous, or showed the least displacement, and which was therefore the one nearest the true focus. We had then eight negatives of the spectrum in each of which the camera focus was nearly exact, but the collimator focus varied from 14·0 to 17·5 by half millimetres. On comparing these negatives it was seen that there was practically no difference as regards the displacement of the lines in the centre of the spectrum, but the length of spectrum in which there was no displacement varied in the different series. That is to say, there was a longer range in sharp focus at collimator settings of 15·0 and 15·5, with a slight advantage to 15·0, than at 14·0, 17·5 or the intermediate settings. This was taken as showing, not that between 15·0 and 15·5 was the focus of the collimator, but that at that focus the curvature of field of the camera lens was reduced to a minimum. However, so far as the centre of the spectrum was concerned, there was practically no difference in any of them. I believe that 15·6, the collimator focus as determined by Schuster's method, is nearly exact, but that by moving the slit about half a millimetre away from the lens a greater length of spectrum can be brought into sharp focus. Hence the final setting of the collimator lens was fixed at 15·2, and as the changes in focus due to temperature are very slight it remains at that setting.

Focus of Camera.

As previously stated the accurate focussing of the camera is much more important than that of the collimator, and here one cannot depend upon the test of definition as the focus may be changed through a millimetre, an amount fatal to accuracy in line of sight work, without appreciably affecting the sharpness of the lines. The method of focussing the camera lens evolved from Newall's method, for focussing the collimator and a modification of which is described by Hartmann, *Astrophysical Journal,* vol. XII., p. 45, is now always employed, and the focus is tested almost every night the spectroscope is used. The method, as above stated, depends upon the displacement of the spectral lines on a plate not in focus, when the pencil which forms them has its centre of intensity separated by a sensible distance from the centre of the objective. Practically, the procedure is as follows. By a pair of diaphragms or windows situated close in front of the slit, which will be presently described, two spectra can be made on the same plate side by side, or rather one spectrum about $\frac{1}{3}^{mm.}$ wide along the centre of the plate has placed on each side spectra, each about a millimetre wide. These spectra touch each other so that when there is no displacement of the lines they appear continuous, but the slightest displacement is at once apparent. An opening was arranged below the collimator lens in which a brass plate slides. This plate has a rectangular opening about 12 mms. wide and 30 mms. long, and the position of this opening is regulated by stops so that in one position it allows a pencil of light of half the aperture to pass through the prisms near the refracting edge, and in the other position near the base. The centre spectrum is made through the refracting edges, and the outside spectra through the bases of the prisms. Hence the centres of intensity of the two pencils through the camera objective are separated by about 12 mms., and if the camera is not in exact focus the lines of the spectrum will not be continuous. The method is so sensitive that, if the plate is 0·05 mm. distant from the true focal plane, a displacement of the lines is noticed. The camera was originally furnished with a plain index and scale reading to millimetres only, but it was found necessary to rule and apply a vernier to read to tenths and to estimate to twentieths

of a millimetre. The importance of accurate focus in line of sight work cannot be too highly emphasized, for, as the method outlined above shows, any inaccuracy of focus will result in a relative displacement of the star and comparison lines whenever, as often happens, the centres of intensity of the illumination pattern of star and comparison light do not exactly coincide.

Adjustment of Prisms.

The prisms of the prism train are attached to a minimum deviation device which is connected with and actuated by the camera, and the range is such that any part of the spectrum may be brought to the centre of the field. This is very convenient for general work, but for line of sight determinations, where one part of the spectrum only is used, and where constancy of position of the prisms is essential, it is not at all desirable. Screws passing through the top of the box and pressing on the top of the prism cells are provided to fix the prisms in position, but sufficient pressure for that purpose will also induce unequal strain in the glass and spoil the definition. As the collimator and camera lenses were corrected for H γ, the camera and train were so placed that this was the central ray, and screws were inserted, passing through the base of the box and the arms of the minimum deviation device into the base of the prism cells so that they could be clamped to the base as firmly as desired, without fear of inducing any strain in the glass. After this had been done the prisms were carefully readjusted for minimum deviation by loosening the strips along the bases, and shifting them to the minimum position, the spectrum for the first and second prisms being observed through holes cut in the outer semicircular side of the prism box. The strips were then again fixed to keep the prisms in this position, and the top plate with its circular piece of cork which holds the prisms down to the base of the cell was so adjusted as to put only sufficient pressure on the prisms to hold them firmly in position without causing sufficient strain to affect the definition.

The Slit and Slit Diaphragms.

The diaphragms provided in front of the slit for making star and comparison spectra of the right width and in the right position were a modification of Hartmann's device described in the *Astrophysical Journal,* vol. XII., p. 46, and were attached to the slit head. To change from the opening through which the star was exposed to the opening for the spark, the brass plate containing these openings was moved between adjustable stops. As displacements of the lines were sometimes noticed in two spark spectra taken side by side through these windows, it was feared that the sliding of this brass plate might induce strains in the slit. This arrangement was dismounted and I made the one shown at A, fig. 3, to replace it. There are two separate diaphragms, one for the star light, B, fig. 3, having an opening about 0·3 mm. wide in the centre, all the rest of the plate over the slit being cut away except two narrow bars about 0·2 mm. wide to limit the star light. This was done for convenience in setting on the slit and guiding. The diaphragm for the spark light, which cannot be seen in the figure as it is turned down on the slit ready for use, has two openings each about 1 mm. wide, separated by an opaque bar, about 0·35 mm. wide, which is central and occupies the same position on the slit as the opening for the star light. These are mounted on adjustable pins so that either can be readily turned down in position, while the whole arrangement is mounted on an arm clamped to one of the supporting tubes, as shown in the figure. It can be placed at any desired distance in front of the slit, or at once moved away to leave the slit entirely free if desired. It does not touch the slit or slit head at all, and hence all chance of displacement of the lines from this cause is avoided. It is also much more convenient in use than the old arrangement. The window for the starlight is only turned down at first to get the star image central, and occasionally throughout the exposure to ensure that the required width of spectrum is being uniformly exposed. When the diaphragm is continuously in front

of the slit, as was the case in the old pattern, not only is the guiding more difficult owing to the short length of slit illuminated by the diffuse visual portion of the star image, but also part of the light in the converging cone of rays will be cut off by the edges of the opening, where the image approaches the ends of its range, as they are upwards of a millimetre above the edges of the slit jaws.

In the tests for flexure to be presently described, I noticed that, even when there was no movement of the telescope and spectroscope between exposures of the adjacent spark spectra, one made through the star, and the other through the spark windows, there was sometimes a displacement of the lines of one spectrum with reference to the other. After the diaphragms had been changed as above described, this could only be due either to the slit or the comparison apparatus. An examination of the slit jaws showed that they were not sharp, but consisted of two flat vertical surfaces about 0·7 mm. wide. One could not say what part of the jaws acted as the source of light, and the focus would be uncertain and besides trouble might arise from reflections between these flat and nearly parallel surfaces. The slit was taken apart, the jaws bevelled off to a sharp edge and ground perfectly straight. Great care was taken to ensure that the edges of these two jaws lay in one plane perpendicular to the axis. Even when this had been finished a photographic test by adjacent spectra showed occasional displacement of the spectral lines, and there only remained the comparison apparatus to be examined as the cause of the trouble. I may say that this work was done previous to the evolution of the focussing method above described, so that the camera focus may have been inexact to the extent of three or four-tenths of a millimetre. This amount of displacement of the sensitive surface from the focal surface is quite sufficient to cause a marked displacement of the spectral lines provided there is any faulty centering of the star or spark light.

The Comparison Apparatus.

An induction coil by Queen capable of giving a 15-inch spark is used in conjunction with six half-gallon jars in parallel to supply the energy for the iron spark which has been used entirely for the comparison light. The spark gap was originally mounted to one side of the collimator tube, and the spark light was reflected into the slit to one side of the light from the star or source to be examined by a small diagonal prism. This was changed to a direct mounting of the terminals and condensing lens in the optical axis of the collimator about 80 mms. above the slit, C, fig. 3. When the star spectrum is being photographed the whole apparatus is swung back out of the way, it being attached to one of the supporting tubes of the spectroscope by a clamp which allows it to be rotated at will. As it was not possible to be sure of its swinging back to the same position, a stop, D, fig. 3, was clamped to the other supporting tube against which the comparison apparatus could be rotated, and always return to the same position.

The angular aperture of the condensing lens is much greater than that of the collimator, and this should, theoretically speaking, ensure the uniform illumination of the collimator objective by the spark light, even if not in exact adjustment. However, as the displacement of the lines of adjacent spectra photographed one immediately after the other on the same plate, under, as far as could be judged, similar conditions of intensity and position of the spark, was still sometimes present, it was evident that something must be done to get rid of this if accurate results were to be obtained.

The iron wire, pieces of wire nails being generally used, was held in two forcep-like clamps, but their construction did not ensure their being held concentrically nor even firmly. These were discarded and replaced by small brass rods having a hole bored centrally in one end into which the wire was slipped and fastened by small screws. These rods were also, after they had been adjusted, firmly clamped by screws in their holders so that they could not be accidentally shifted. The central and invariable position of the terminals was thus assured, and they were purposely made small in diameter so that the spark could not shift its position very much by jumping from one side to the other. In order to render the illumination more uniform, a small

piece of finely ground glass was placed about midway between the spark gap and condensing lens. It was tried in various positions, but the one just mentioned seemed to best fulfil the requirements. A second piece of ground glass was also mounted on the attachment carrying the diaphragms which could be turned down in front of the slit if desired. It does not seem to have any effect beyond increasing the exposure and is not now used for that purpose. However, when rendered opaque by a piece of black paper, it can serve as a shield to prevent light getting through the slit.

Tests of the uniformity of illumination are always made visually before starting a night's work and sometimes photographically by placing a small plate over the aperture of the collimator lens. The stop, D, fig. 3, is adjusted visually as follows. If the eye be placed in the direction of one of the bright iron or air lines, one can see the whole camera lens in the light from that line and can readily judge of the uniformity of illumination. By moving the spark apparatus back and forth past the centre, the position of uniformity, which extends over two or three millimetres of movement, can be readily judged and the spark apparatus is placed at the centre of this range. Then the stop is brought up to just touch the arm, and after this is done the comparison arrangement can always be returned to the same position. The relative positions of spark, condensing lens, and slit are so adjusted that the image of the spark is formed about a centimetre above the slit. Thus only a diverging pencil strikes the slit and the adjustment required is not so accurate as if the image were focussed on the slit.

After these changes had been made no further displacements of the spectral lines were observed even with considerable mal-adjustment of camera focus. If the camera focus has been adjusted carefully in the way above specified, any slight lack of uniformity in the distribution of the spark light should be without effect on the position of the lines.

Flexure of the Spectroscope.

The greatest difficulty encountered in putting the spectroscope into condition to do accurate work was that of flexure. Owing to the design of the instrument, which aimed to make it of a universal type, the prism box has no adequate support. It is fastened by a single screw to the rotating table, which carries the grating or the single prisms when used with low dispersion, which from its nature can not be rigid, and is further secured by two rods reaching down from the box and clamping to the edge of the divided circle which is a thin ribbed plate of brass not sufficiently stiff to furnish much support to the prism box. The outer end of the prism box which carries the camera is entirely unsupported and could be moved by a pressure of the hand three or four millimetres to one side or the other. I had always suspected that flexure might cause trouble, but had no idea, until I made a test, of the extent of the displacement of the spectral lines that would be caused by a movement of the telescope with spectroscope attached through two hours in right ascension, which would be the duration of an exposure on a faint star. The test was made in a similar manner to those above described, by making a spectrum of the iron spark through the star diaphragm, and, after moving the telescope, a second adjacent spectrum through the comparison diaphragm. Any shift of the lines due to flexure will at once be shown, and the shifts at first were very marked. A movement of the telescope through two hours showed in some declinations a displacement of the lines equivalent to a velocity of 20 kms. per second. A rotation of the spectroscope of 90° around the optical axis, when the telescope was at hour angle 0h. declination 0°, showed a shift equivalent to about 50 kms. per second. These figures at once show the impossibility of obtaining accurate results with the spectroscope in its original form, and I set myself the task of rendering it capable of reasonably good work until a modern, thoroughly rigid spectrograph could be obtained. The framework of the instrument consists of a hollow built up structure of rectangular section, seen in fig. 3, which is fastened by four hinged clamps to the two supporting tubes of the adapter. The collar into which these tubes clamp can turn on an inner collar, which in turn screws into the eye end of the telescope. The two tubes are of 1⅜-inch diameter of steel thick

enough not to bend appreciably under the weight of the spectroscope. It was thought preferable to attach any stiffening trusses direct to these tubes rather than to the spectroscope frame which is not stiff enough for that purpose. The first truss that I made, shown at E, fig. 3, was built of thick sheet brass screwed to a brass rod which entered into clamps directly below the spectroscope frame, on each tube, one of the clamps being shown at F. This triangular shaped brass plate, which had a second plate screwed at right angles underneath, extended diagonally across the back or base of the prism box almost under the third prism. It was firmly screwed to the base of the box and served to prevent flexure at the outside edge of the prism box and the lower end of the camera. The upper end of the camera was already provided with a brace, but this was further stiffened by a diagonal connecting rod. The prism cells, as before mentioned, had already been firmly clamped to the base of the box so that no displacement could arise there.

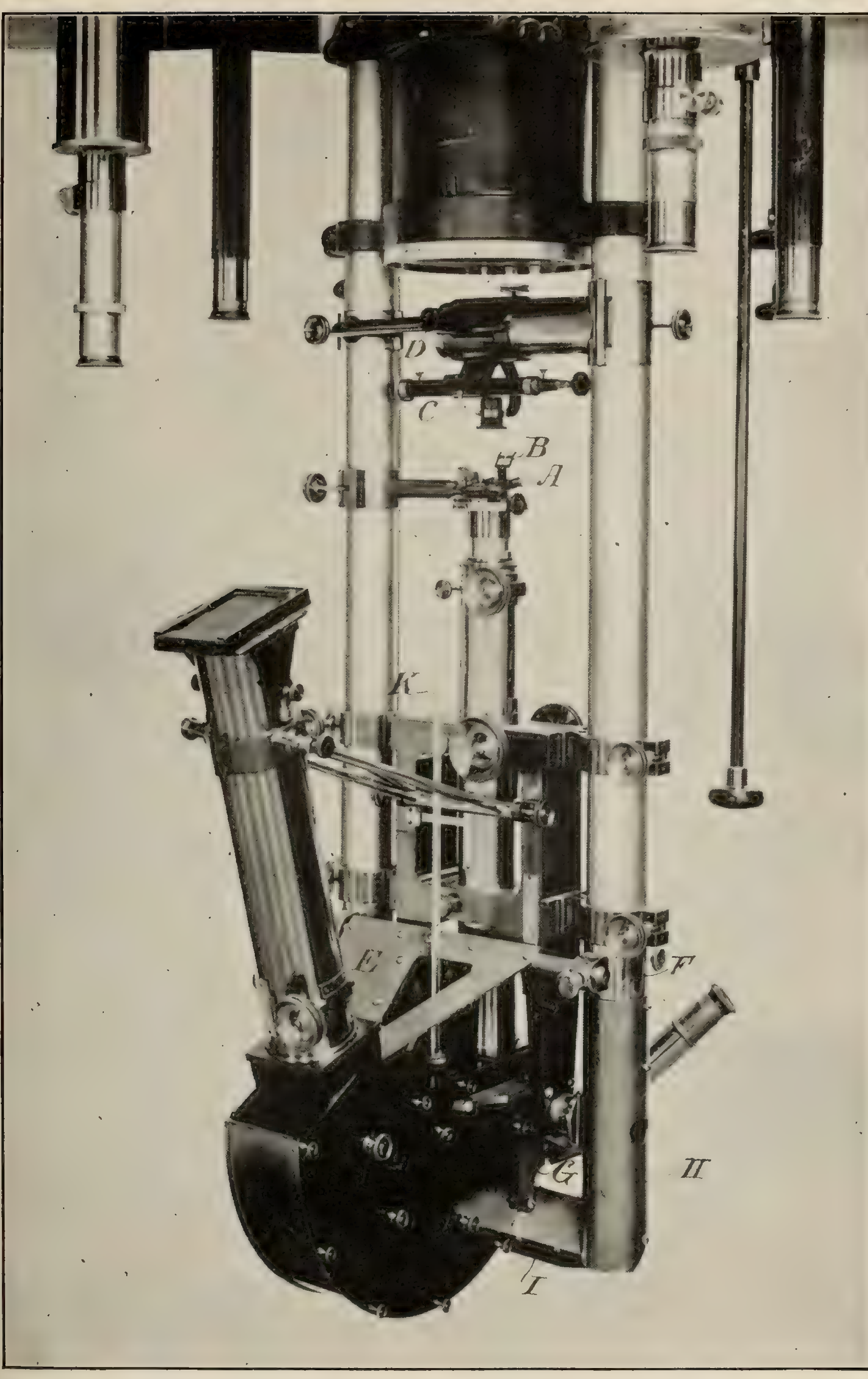
So far as stiffness of the outer end of the prism box is concerned, the spectroscope was immeasurably improved by this truss. A test of the displacement showed that the flexure had been much reduced, as a movement of two hours caused a displacement equivalent to about 5 kms. per second.

This was still too great, and a careful examination showed that it was probably due to a movement of the collimator end of the prism box, which was only supported by one projecting arm of the framework, as the truss already applied was sufficiently rigid to prevent any appreciable flexure of the camera end. A built up brass T piece, G, fig. 3, of suitable thickness, was inserted between the other projecting arm, to which it was firmly screwed, and the top of the prism box. The arms of the T were made sufficiently long to extend to the outer walls of the box to which they were also screwed, the upper plate not being thick enough to form much support. The introduction of this piece further stiffened the instrument and resulted in a reduction of the displacement to an amount equivalent to between two or three kms. per second.

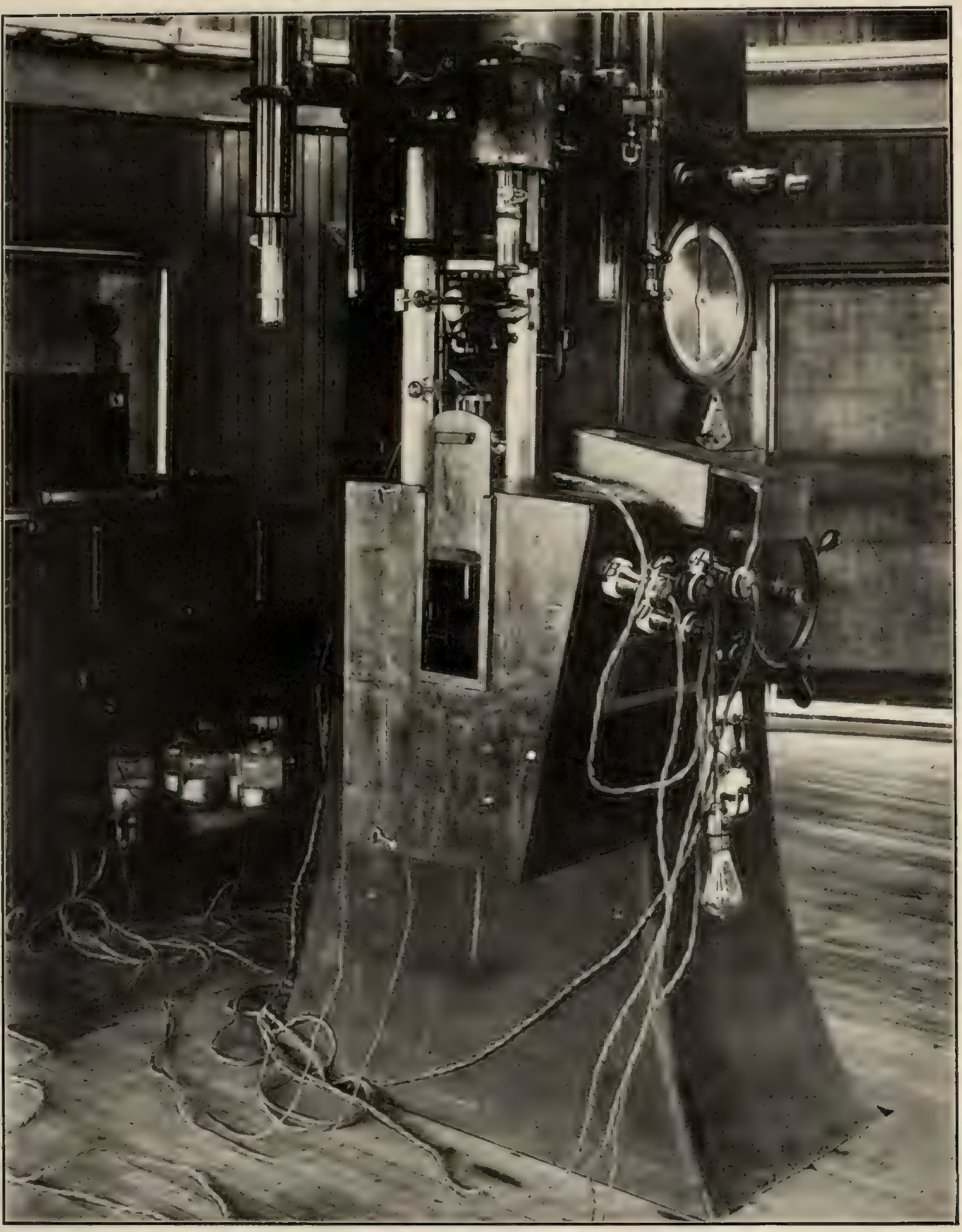
As this displacement was still rather great, I determined to make an effort to further reduce it, and I removed the swinging arm, which carried the telescope or camera when used with the single prisms or grating, the verniers on the circle and other small attachments. Two pieces of 2-inch brass tubing were bored out to fit the projecting ends of the 1⅞-inch supporting tubes, and these, one of which is shown at H, fig. 3., were firmly joined at their lower ends by a rigid U-shaped truss, I, fig. 3, built up of brass plate to which the outer edge of the prism box was screwed. The projecting arms of the framework were also firmly attached to the tubes, H, while the prism table and divided circle were rigidly connected together by a screw and block. The whole instrument with these additions seemed now very rigid, and a test showed that the displacement of the lines due to flexure was now reduced, at the most, to an amount equivalent to from 1 to 2 kms. per second while in some declinations of the telescope the flexure was hardly appreciable. This amount of flexure would not affect the final result by half the velocity mentioned owing to the displacement being compensated to a considerable extent by a similar displacement of the comparison lines which are exposed for half the time before, and half after the exposure on the star. As I could contrive no further means of stiffening the instrument without rebuilding, it seemed preferable to keep it intact for work on other parts of the spectrum and to design and construct in our workshop a thoroughly rigid modern type of spectrograph for the express purpose of accurately determining the radial velocities of the brighter stars.

The Temperature Case.

It was realized from the first, that it would be necessary to provide some means of keeping the instrument at constant temperature during an exposure, for not only does the deviation and dispersion of the prisms change with change of temperature, but the expansion of the metal parts would also be liable to cause differential displacements of the star and comparison lines. Either cause would be liable to introduce errors in the velocity determination which, owing to the small displacements measured



5146 FIG. 3.—The Spectroscope as arranged for Radial Velocity Work. p. 56



5146 Fig. 4.—The Spectroscope and Temperature Case ready for Work. p. 56

1 mm. on the plate being equivalent to about 1,300 kms. per second, might easily be comparatively large.

A light wooden case was constructed by the carpenter at the observatory, under my direction, to inclose the whole spectrograph with the exception of the upper part of the collimator tube containing the slit. This case was made in two pieces to permit of ready removal, and was fastened to the supporting tubes only, not touching the spectroscope proper at any point. Doors and slides admitted to the plate holder, the focussing screw of the camera, and for the insertion of the focussing diaphragm, as the focussing can only be accurately performed when the temperature of the instrument has been maintained constant for some time, so that the temperature of the interior of the prisms is in a steady state. A glass window in the side of the case permits the reading of the thermometers, of which one has its bulb within the prism box and is seen at K, fig. 3, while the other is inside the case.

The box is heated by the passage of an electric current through coils of No. 28 German silver wire, which are wound on light wooden frames, the wire entering saw cuts in the edges, so as not to become displaced. Two larger coils are placed on the sides of the case directly opposite the prism box, while two smaller coils are placed on the end one on each side of the camera. The resistance of the coils in series is about 100 ohms and current from the lighting service at 105 volts quite rapidly overcomes a lowering of the external temperature. It would be preferable to be able, by means of a variable external resistance, to so regulate the current through these coils, that the temperature be only slowly raised the required amount, since the oscillations of temperature in the outer case would then not be so great. The pressure of other work and the provisional nature of the installation has, however, prevented me from so arranging it. The current is applied automatically, when the temperature drops, by an electric contact minimum thermometer completing the circuit, by means of a small polar relay seen under the induction coil in fig. 4, between the lighting current and the heating coils. The receptacles with attaching plugs and flexible coils lead, fig. 4, A from the heating coils to the points of the relay, B from the thermometer contacts to the coils of the relay, and C to the lighting circuit respectively, while a fourth D as shown furnishes a convenient light for reading the thermometers, &c. The minimum thermometer used is not sensitive enough and is moreover too sluggish in action, owing to the expanding liquid being a poor conductor of heat, the thermometer in the case showing an extreme range of temperature of about 3° C., which is by far too great for the best results. Although the fluctuations are so smoothed down in getting through the blanket wrappings of the instrument as not to show on the inner thermometer, they must nevertheless have some effect on the expansion of the metal parts and, if no other harm is done, will render the spectrum lines more diffuse than would be the case under constant temperature conditions.

For the new spectrograph it is proposed to use much more sensitive and rapidly responding mercury thermometers, so that the range will not exceed 0·2° C., and moreover, to provide some means of mechanically stirring the air to prevent temperature stratification. In the present temperature case, there may be as great a difference as 3 or 4° C. between the upper and lower parts of the box, and this could be to a great extent prevented by a small electric fan for stirring the air inside the case.

The Correcting Lens.

After the thorough tests and the modifications and additions just described, I expected to get results free from systematic error, but star spectra made with the instrument still gave velocities up to and sometimes greater than 2 kms. per second different from the mean of the values obtained by other observers of the same star. As these values were sometimes greater and sometimes less, it was evident that the cause of the trouble was in the instrument itself. It could not be due to accidental errors of measurement as the mean error of the radial velocity of a star, as obtained from the values given by the individual lines, was only from 0·4 to 0·5 kms. per second. It

did not seem likely that a systematic error of such magnitude could arise from any of the causes previously discussed and overcome, and so I was led to examine the distribution of the star light over the collimator objective from the following considerations. Supposing the star light were so distributed that its centre of intensity did not coincide with the optical axis, then, provided the camera were not exactly focussed, the positions of the star lines would be displaced to one side or other of their position with uniform illumination, and therefore also to one side or other with respect to the comparison lines, which are presumably formed under uniform illumination and consequent coincidence of the centre of intensity with the optical centre. The amount and sign of this displacement would depend upon the distance between, and the relative positions of the centres of intensity of star and comparison light, and also on the distance between, and relative position of, the sensitive and focal surfaces in the camera. Even though the camera were exactly focussed for one plate, it does not necessarily follow that it will be exact for another plate, as, when the plates are supported at the ends of the holders, the irregular curvature of the glass may be such as to introduce a difference in the position of the sensitive surface easily as great as the tenth of a millimetre. An incorrect adjustment of the camera focus of one-tenth of a millimetre causes, as previously stated, a sensible displacement of the lines, equivalent to 2 kms. per second, when the centres of intensity of the two sources are separated by 10 or 12 mms.

It is hence evident that the errors observed could easily be caused by an unsymmetrical distribution of the star light over the collimator objective, and in order to avoid this error the camera must be focussed as exactly as possible, and the distribution of star and comparison light made as uniform as possible. As the comparison light had already been attended to, there remained only to examine the distribution of the star light.

This was done both visually and photographically in exactly the same way as was adopted for the spark light, though the chief dependence was placed on visual observations with a bright star. A very few minutes sufficed to show that the star light was distributed very irregularly and unsymmetrically over the collimator and camera lenses. It was readily seen that a slight difference in the guiding might easily cause a displacement of the centre of intensity several millimetres to one side or other of the optical centre, and a consequent displacement of the spectral lines, except when the sensitive surface exactly coincided with the focal surface. Even then owing to curvature of field of the camera lens, only a short part of the spectrum could be in exact focus, and at the ends of the measured portion the lines might be displaced, thus causing an error in the velocity.

The slit was placed in all positions, both at and near the apparent star focus, and to considerable distances within and without, but in no position could the illumination be made even approximately uniform. Although the pattern on the camera objective observed visually always appeared irregular and rapidly changing, probably due to unsteadiness of the air, it had, when the slit was within the focus, the general form of a diametrical bar, which became narrower as the distance of the slit from the focal point increased. When the slit was without the focus the diametrical bar parallel to the slit still appeared with the addition of a peripheral ring.

The position of the correcting lens was then altered from its computed position in each direction without any improvement in illumination and the lens itself was inverted in its cell with the result of making matters worse. Acting on a suggestion of Dr. Ralph Curtiss of the Allegheny Observatory, to whom I am much indebted for this and other help, I made a double slide carrier for the correcting lens, adjustable from the eye-end, which allowed the lens to be collimated exactly by means of a bright star. This also was without useful effect, so the cause of the trouble had to be looked for in another direction.

It was noticed that, when the slit was made very narrow, the illumination became more uniform, which was likely due to the diffractional spreading of the light. Furthermore, when the slit was made about 0·2 mm. wide, the illumination became uni-

form, and the inference must be that, with a narrower slit, part of the image was cut off by the jaws, but that the whole image got through with a 0·2 mm. slit, equivalent to 7 seconds of arc in the focus of the refractor. The diameter of the central diffraction disc, or rather of the first dark ring as given by the formula $d = 1 \cdot 22 \frac{\lambda}{r}$ is, for a 15-inch objective, about 0·6 seconds for the photographic light. As unsteadiness of the air will much confuse and apparently enlarge this image, it is probable that the effective diameter will be in the neighbourhood of 2 inches. Newall's considerations in regard to tremor and scatter discs indicate a central condensed part of the image he calls the 'core,' about 2 seconds diameter surrounded by a diffuse scatter disc 5 seconds to 10 seconds diameter. The appearance here seemed to indicate a core about 7 seconds diameter, which is much too large, and evidently something was radically wrong with either objective or correcting lens, or both. This was also indicated by the very long exposure required to obtain measurable spectra. For instance α Boötis with slit width 0·02 mm. required 15 min., α Arietis slit width 0·025 about 75 min. Such exposures are upwards of twice as long as those given by Lord of the Emerson McMillin observatory with a spectroscope of practically the same dispersion on a 12½-inch telescope.

In order to determine where the trouble lay, the correcting lens was removed and the slit brought into the focus for different parts of the spectrum. On examining the illumination pattern the regularity and uniformity of illumination was much improved at all slit widths, and at 0·05 mm. it was practically uniform. This is equivalent to an effective diameter of the star image about 1·8 seconds, and is no larger than is to be expected in average seeing. A test of the exposure time required in the neighbourhood of $H\gamma$, with and without correcting lens, showed that for equal intensity of spectra about double the exposure was required in the former case. As accurate guiding on the visual image with the slit in focus for $H\gamma$ is almost impossible owing to the large size of the visual image, this would increase the above disparity in exposure times. It was evident therefore that the trouble lay in the correcting lens.

In order to obtain more information about the character of the star image the spectrum of a bright star, Vega, was photographed with the slit in different positions in the neighbourhood of the star focus. In order to admit the whole image, the slit was made about half a millimetre wide, and the spectroscope was turned so that the edges of the jaws were parallel to an hour circle to prevent the spectrum being widened by irregularities in driving. If the star image were good the spectrum taken with the slit at the focus should be the narrowest and they should become wider in those taken with the slit at increasing distances from the star focus. On the contrary, however, there was very little difference in the width of the spectra, taken within a range of about 8 mms. on each side of the focus, the width in each case being about 6 seconds or upwards. In another series taken with shorter exposure, the width was practically the same, but in the spectra outside the focus there was a condensed central strip having a diffuse strip on each side. A series of the photographs of the image itself as given by the objective and correcting lens showed a similar effect, the smallest image at the focus, being about 10 seconds diameter, while those on each side increased in diameter and consisted of a central nucleus surrounded by a more or less expanded disc. The appearance both in the case of this image and of the spectra seemed to me exactly like that produced by spherical aberration.

In order to further localise the trouble, a similar series was made with the correcting lens removed and the slit at the foci of different parts of the spectrum. In these spectra the part near the wave length in focus only, was linear and about 3 seconds wide, while it expanded into a broad band on each side of this portion. The intensity in this broad strip was, however, quite uniform without any appearance whatever of a central nucleus as shown in the other series.

The trouble, as stated above was, diagnosed as probably due to spherical aberration, and the correcting lens was taken out of the cell and examined carefully. There were apparently no defects in the surfaces, for, so far as could be seen without

specially testing, they were all spherical. One cause of the trouble might be the wrong placing of the elements in the cell, for if one of the elements were inverted it would probably introduce sufficient spherical aberration to cause the observed effects. The lens consisted of a double equi-convex, presumably of flint glass, and a double concave of crown. The curvature of the outside surface of the concave was the same as that of the convex, while the inside surface, against the convex lens, was of greater curvature. As it seemed probable, when one of the surfaces of the concave was of the same curvature as the convex, that it had been intended to place them together, the paper separators were moved to the other side and the concave inverted so that the contact surfaces faced each other.

This seemed to solve the difficulty, for the illumination pattern on the collimator and camera lenses was now found to be practically uniform for all slit widths, and had the same appearance as that given when the correcting lens was removed. A slit 2 seconds wide seemed to admit practically the whole star image, while the necessary exposure for measurable star spectra was diminished by at least 50 per cent.

So far as regards the removal of systematic error due to the eccentric position of the centre of intensity of the star light, the negatives made since, so far as measured, show no signs of such error, but give accordant results.

Although the various difficulties encountered in making the spectroscope suitable for accurate velocity determinations have prevented as much work being accomplished as could otherwise have been done, they have not been without advantage, for they have certainly been an education on spectrographic peculiarities and causes of error, which could not otherwise have been obtained. The new spectrograph for purely radial velocity work, which I have designed and which is now being constructed in our workshop, is so arranged as to avoid all the difficulties encountered in working with the present instrument, and it is hoped the new instrument will prove to be as efficient as possible for determinations of velocity in the line of sight.

REDUCTION OF SPECTROGRAMS.

General.

Since commencing work with the spectroscope last November, some 350 negatives of stellar spectra have been made. This does not include several hundred negatives of the spectrum of the iron spark made during the testing, adjusting, and remodelling of the spectroscope. Of the early star negatives only a few have been measured and reduced, owing to the systematic errors present in most of the earlier work, and these were reduced more for the sake of determining the condition of the instrument and the progress made in overcoming the difficulties, than for the actual determination of radial velocities. Since the spectroscope has been placed in a condition to do reasonably accurate work, about June 20 of this year, the suitably exposed negatives are being measured and reduced by Mr. Harper as rapidly as possible, but as each takes upwards of a day, the progress made is slow. Some of those he is measuring will be included in this report and the results will follow this description of the method.

Those measured so far are certain of the brighter stars, chiefly of the solar type, which have been chosen, by agreement among astronomers engaged in radial velocity work, as suitable for periodical observation. When their radial velocities have been well established by the combination of the measurements of many observers using different methods, they may be used at any time as a check upon the performance of the spectroscope, when none of the planets, whose velocities with respect to the earth can be readily computed, are available. For this purpose, as my difficulties with the correcting lens show, they may be more suitable than the planets which have a sensible disc and give uniform illumination of the collimator lens, when a star would not do so. Another purpose, that may be served by such measurements, is to furnish data with regard to the wave lengths of certain lines in the star spectrum, which constantly give discrepant values of the velocities.

Some stars known to be spectroscopic binaries, double stars whose components are too close together to be visually resolved, and only recognized as binaries by their variable radial velocity, have also been observed, but no measurements have yet been made of the spectrograms obtained. The determination of the velocity curves of spectroscopic binaries offers a very wide field for radial velocity work, and one which is scarcely at all occupied. Of the 150 spectroscopic binaries discovered up to the present, less than 20 have had the elements of their orbits determined, and it seems to me that work of this nature requiring persistent and continuous observation is very suitable for this observatory.

Theory of the Method.

The theory of the method of determining the velocity of stars in the line of sight by the spectroscope, depends upon Doppler's principle, which can be simply stated as follows. When any source of light is approaching the observer, the apparent period of the oscillation is decreased and when receding increased. A simple illustration of this principle is given by the increase of pitch of the whistle of an approaching locomotive. When the period is decreased, the length of the wave is diminished, and conversely when the period is increased the wave length is also increased. Hence it follows that a recession of the star causes a displacement of the lines in the direction of the longer wave length or towards the red end of the spectrum and increases the apparent wave length, while an approach of the star displaces the lines toward the violet end of the spectrum. Such a displacement of the lines is well shown in the spectrum of Jupiter, fig. 6. The slit was set parallel to the equator and one side, the lower, in the spectrum is approaching and the other receding with a velocity of 12·8 kms. per second. This is well shown by the inclination of the planet lines with respect to the comparison lines.

The precise relation is $V_s = \frac{299860}{\lambda}$, where V_s = velocity of the star in the line of sight in kilometres per second.

299860 = velocity of light in kilometres per second.

λ = wave length of the line considered in units of the ten millionths of a millimetre.

If the spectrum of a star be photographed, and beside it the spectrum of some terrestrial source such as the iron spark, the wave lengths of whose lines are exactly known, the apparent wave lengths of the star lines can be accurately determined by comparison with the terrestrial spectrum. If, moreover, the elements producing the lines in the star can be identified, then the wave lengths of these lines in the star at rest are known. The difference between the latter values and the apparent wave lengths, as determined from the comparison spectrum, gives us the displacement or change in wave length of each line due to the radial motion of the star. These differences multiplied by $\frac{299860}{\lambda}$ give us the velocity in kilometres per second, due to the lines, while the mean gives us the velocity of the star with reference to the observer.

The Spectrograms.

The negatives, which are made on plates, 5 by 7·5 centimetres in size, have the comparison spectrum, the iron spark, photographed on each side of the star spectrum, the method of accomplishing this by slit diaphragms having been previously described. The time of exposure on the comparison spectrum is divided into two, one half being given just before, and the other half just after the exposure on the star spectrum. The star spectrum is made about 0·25 mm. wide, while the comparison spectra are each about 1 mm. wide, and separated by a strip of unexposed film about 0·1 mm. wide from the star spectrum. The whole spectrum is about 5·5 cms. long, but, owing chiefly to curvature of field of the camera lens, only about 2 cms. in the middle of its length is

in sharp focus. The limiting wave lengths in this range are approximately λ 4185 and λ 4535, and it is this portion only which is used in velocity determinations. A reproduction of the measurable portion of a spectrum of α Boötis enlarged about nine times, is given in fig. 6. The linear positions of the lines, both star and comparison, in this strip are determined by a measuring machine.

The Measuring Engine.

The instrument we are using for this purpose is one specially designed for this and similar work, and is made by Toepfer & Son, of Potsdam. It is a very efficient and complete instrument, and has given excellent satisfaction. A photograph of the complete instrument with accessories is shown in fig. 5. Its essential part is the micrometer screw of 0·5 mm. pitch, which moves a carriage on which the negative is placed. This carriage travels in accurately surfaced ways, and lost motion on the screw is taken up by a weight. The negative rests on a piece of plate glass, against which it is firmly clamped by two spring clips whose tension can be regulated and the clips also entirely removed from contact by turning a milled screw. The upper part of the carriage, containing the plate glass holding the negative can be oriented with respect to the direction of movement by turning a milled head. This is to allow the spectrum to be set parallel to the direction of motion of the carriage, or, in other words, so that the horizontal wire in the microscope eyepiece will always remain in the same position on the spectrum as the carriage is moved along the ways. The microscope itself is moved in ways at right angles to the motion of the carriage by a micrometer screw of 1 mm. pitch, and this motion can be read on a micrometer head divided into hundredths and readily estimated to thousandths of a revolution or millimetre. This allows measures in two directions at right angles to each other to be made without shifting the negative and is also very convenient in adjusting the negative. The settings on the spectrum lines are made by means of spider lines in the focus. In one direction there are two, which can be made to coincide or which can be adjusted to any desired distance from each other, always remaining parallel, while crossing centrally in a direction at right angles is a second single wire. The head containing these wires can be rotated through a right angle to permit either the single or double threads to be used for setting on the lines, and also to allow the vertical wire or wires to be set exactly parallel to the comparison lines. The single thread has been used exclusively for setting on the star and comparison lines. Although a double thread could be used to advantage on the emission lines, its use on the absorption lines of the star spectrum would increase the accidental errors of setting to such a degree as to more than compensate for its advantage on the iron comparison lines.

One eyepiece and four objectives, with an extension tube in the microscope body to allow of increasing the distance between eyepiece and objective, give any magnifying power between 8 and 75 diameters. A power of about 25 seems to give the best results, and is accordingly usually used, although if the lines are not very well defined a lower power would be more suitable.

The negative can be placed on the carriage, adjusted in position, and aligned while the microscope is vertical. For the measurement, however, the whole microscope is rotated about a horizontal axis into a nearly horizontal position, the eyepiece is then at the proper height for convenience and ease of reading when comfortably seated in an ordinary chair. In this position with the elbow resting on the table, the right hand just comfortably reaches the micrometer head and makes the necessary setting on the line. The head is of large size, graduated to hundredths, but easily and accurately estimated to thousandths of a revolution. To the left of this head separated by a narrow strip of metal bearing the index mark, is a second head of the same diameter, geared into the first in the correct ratio to read whole revolutions of the screw direct. A reading lens is so placed that one can make these two readings at one time without moving the head to any extent from its position when making the settings.

FIG. 5.--The Measuring Microscope.

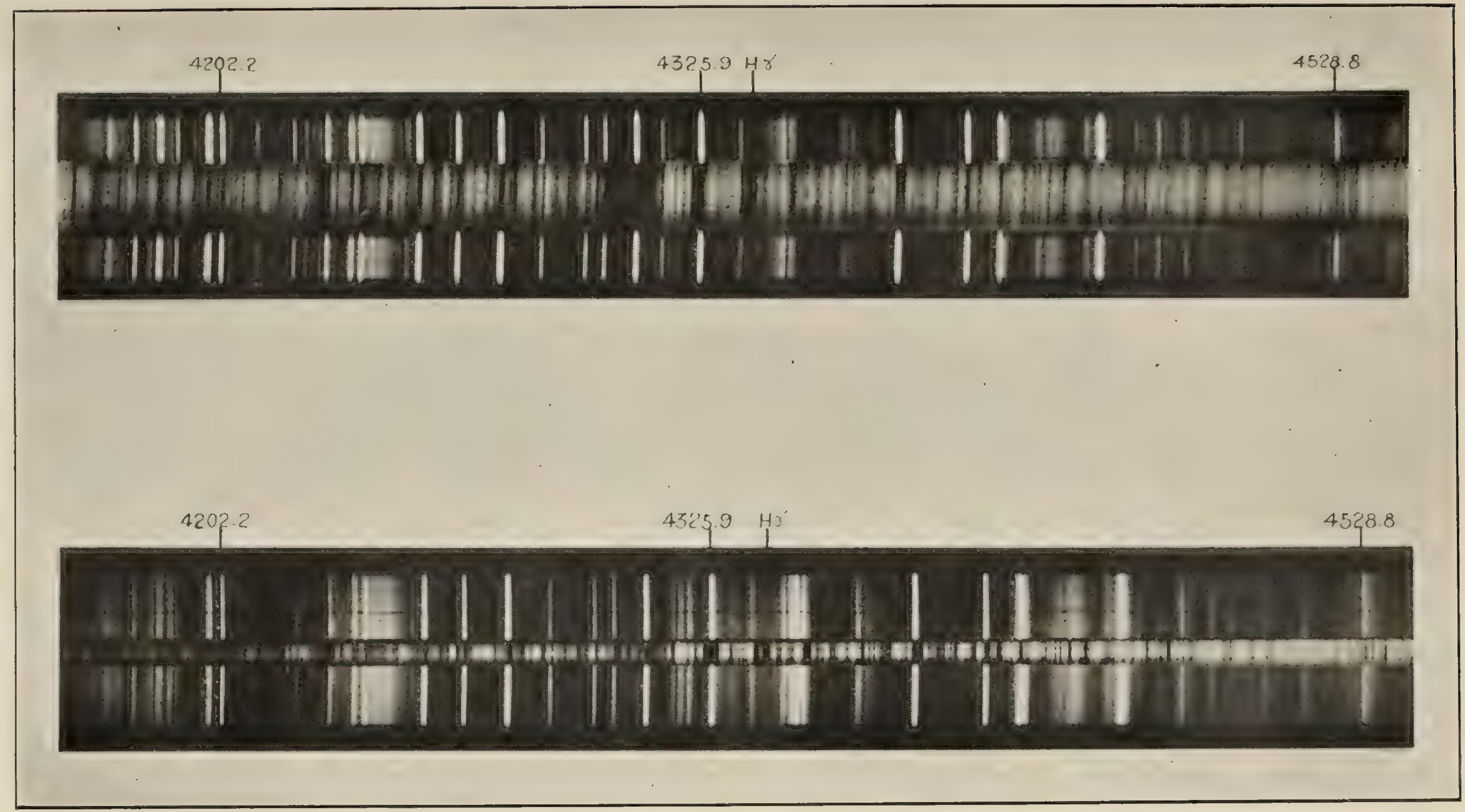


Fig. 6.—Upper Spectrum—Jupiter, Inclination of lines showing Rotation of the Planet. Lower Spectrum—Arcturus No. 325. Enlarged nine times.

The field is very bright and has a decided advantage over the Zeiss comparator in this respect. The Zeiss was used for a short time, but, owing to the double reading on the negative and the silver scale, more than twice the time was occupied in making a measurement with considerably more strain on the eyes. The negative is illuminated from an adjustable mirror below, and the definition and illumination leave nothing to be desired. An attachment for ruling scales, reticles or similar small pieces is provided, which can be readily attached to the bed of the carriage, and is shown at the front of the figure.

Sources of Error in the Measurement and Reduction.

1. *Errors in the micrometer screw of the microscope.*—From the experience of others with similar instruments, these may be safely neglected, as they will be very small in any case compared to the accidental errors of setting, and will also be partially compensatory. As soon as time can be found, however, the screw will be examined for errors in its pitch, whether periodic or otherwise.

2. *Personal error due to the difference in setting on the light star and dark comparison lines.*—The amount of this error may be affected by uneven or one-sided illumination. Fortunately it can be almost entirely overcome by reversing the negative on the carriage after half the settings have been made, and finishing the measurement in the reversed position.

3. *Accidental errors of setting.*—The magnitude of the accidental errors of setting depend upon a number of factors, upon the general quality of the plate as regards sharpness and intensity, upon the quality of individual lines in the plate, and finally upon the experience and carefulness of the measurer. Their influence upon the final result is diminished by increasing the number of settings on each line as well as by increasing the number of lines measured. The custom here has been to make 8 settings, 4 in each position of the negative on both star and comparison lines and to measure about 30 star and 12 comparison lines on each negative of a solar type star. The mean error of the velocity, as determined from a single line, $\epsilon = \pm \sqrt{\frac{\Sigma v^2}{n-1}}$, varies from two to three kilometres per second equivalent in linear measure with the dispersion of the present spectrograph to 0·0015 – 0·0022 mm. The mean error of setting on a good single line, as determined from the residuals of the four settings themselves, is about 0·0005 mm. The difference is probably due to errors in the interpolation formula, in the values of the wave lengths employed, and to displacements of the lines on the negative due to aberration in the spectrograph, or changes in the film during developing and drying.

4. *Errors due to temperature changes during measurement.*—Change of temperature of the screw or plate during measurement will be very likely to introduce errors. Care is taken to maintain the temperature as constant as possible, and to complete a measurement in one setting, so that errors from this source will be reduced as much as possible.

5. *Errors in Wave Lengths.*—Such errors may be of two kinds, errors in identification, and errors in the wave length tables employed. Errors in identification are likely to arise owing to the comparatively low resolving power of a star spectroscope. One cannot be sure of separating lines with this instrument less than about one half a tenth-metre apart and frequently lines with a greater difference than this are unresolved. With solar stars, which so far are all that have been measured, one must take the sun as the type, though it is quite possible and probable that some of the composite unresolved lines in the star spectrogram may have different components, or components with different intensities, than the same composite lines in the sun. In either case, wave lengths taken from solar spectrum tables would not be correct. Evidence of such errors is given by some of the lines employed, which give consistently large negative or positive residuals. They have, however, been included in the

measurements, until more plates have been reduced, when they may, if they act in the same way throughout, be rejected. Their inclusion will, however, hardly affect the final result more than two or three-tenths of a kilometre. Others of the lines may also be in error from the same cause to a less degree, so as not to markedly show in the residuals, but such errors cannot be overcome until we get much purer star spectra than are possible at present.

That errors in the wave length tables employed are present is well known, their magnitude in the best tables, Rowlands and Kayser's may amount to 0·01 tenth-metre and perhaps more. This is equivalent to a velocity of about 0·65 kms. per second. Such errors, however, may partially compensate each other and thus reduce the error of the final result as obtained from the mean of lines extending over three or four hundred tenth-metres.

Reduction to Wave Lengths.

The linear measures of star and comparison lines are reduced to wave lengths by means of Hartmann's simple and convenient interpolation formula, as given in the *Astrophysical Journal,* VIII., p. 218. Wave lengths and linear measures are connected by the relation $\lambda = \lambda_0 + \frac{c}{s - s_0}$

where λ = wave length of the line,

s = micrometer reading,

λ_0, c, s_0 are constants.

To determine these constants, three equations are necessary, and these are obtained from the readings for three iron lines, taken, one near the centre, and the other two near the ends of the range of spectrum measured, which extends usually between the limits λ 4530 and λ 4200 approximately. Three iron lines very frequently used as standards are 4476·207, 4315·255 and 4202·195, but the choice of these lines depends altogether upon the negative; those best defined near the above values are always chosen. The wave lengths of the standards, and the other iron lines measured have been taken from Kayser's iron arc standards in the *Astrophysical Journal,* XIII. p. 334. These values have been considered preferable to Rowland's solar spectrum values, as the wave lengths in the sun may be affected by conditions of pressure, etc., which will give them values different from those of a terrestrial source. On the other hand it is an advantage to use one set of tables throughout for both star and spark lines, and besides it is not as yet definitely settled whether the wave length of lines produced by arc and spark are exactly the same. The difference, if any, is however, very small, and while I decided to use Kayser's values for the comparison lines as likely on the whole to give the best results, Mr. Harper has generally used Rowland's values, chiefly, I believe, because Kayser does not give the wave lengths of several measurable iron lines.

When the three standard lines with micrometer reading and wave length have been selected, the determination of the three constants λ_0, c and s_0 is a simple matter of substitution and reduction, although the actual work is rather long. In the determination of c, one can with little additional work form a check upon the numerical accuracy of the reduction, and this is always performed. When the constants have been obtained, the wave length of each star and comparison line measured is computed from the formula above and tabulated. Some idea of the accuracy of the interpolation formula, and of the magnitude of the accidental errors on the comparison lines is obtained from the magnitude of the differences between the computed wave lengths and the wave lengths as given by Kayser. In most of my plates, these differences have not exceeded two or three hundredths of a tenth-metre, except at the red end of the spectrum beyond the standard line, where they sometimes amount to two tenths of a tenth-metre. The question then arises, as to the means to be employed of determining the correction to be applied to the computed values of the star wave lengths; whether to interpolate to the nearest comparison line, or to run a smooth curve through the points whose position is given by the corrections to the comparison lines, and to take

corrections to the star lines direct from this curve. I have generally preferred the latter method as making some allowance for the accidental errors of setting on the comparison lines.

The apparent wave lengths of the star lines now being known, there remains to identify these lines, and to determine their wave length when unaffected by the motion of the star. For the solar stars, which so far only have been measured, Rowland's Solar Spectrum Tables are used. Knowing the photographic purity of the spectrum, which, for the fast plates necessary in star spectra is about 8,000, one can form an idea whether a star line is single in the solar spectrum, or whether it is a blend of two or more solar lines. For this a good map of the solar spectrum as Rowland's or Higg's, is of service, but the main dependence is placed on the tables. If the line is single, all that is necessary is to put down the corresponding wave length, but, if composite, it is necessary to determine the number and intensity of the lines entering into the blend, and form their weighted mean. Each observer seems to be a law unto himself in this respect, for, in comparing wave lengths of the same line as used by different observers, I find as many as three or four different values. Indeed one observer uses for different solar stars, and in some cases for different negatives of the same star, two or three values of the same line, differing by from two or three hundredths to over a tenth of a tenth-metre. The practice followed here has been to judge from the appearance of a star line on the negative, and the appearance of the same line or lines in the solar spectrum, what lines enter into the blend. These being compared with the tables, one can generally form a good idea of the lines entering into it, and their weighted mean gives the wave length to be applied. Following the practice of others, I have included lines in these blends, of intensities 0 and higher on Rowland's scale. The residuals of lines determined in this way have usually been of reasonable magnitude, and the adopted wave lengths are probably nearly correct. As previously stated some residuals are consistently large, and when more data has been accumulated those lines will probably be rejected. It is, however, not only the blends, but some single lines also that are at fault in this way, notably 4494·738, which has always given a residual about 4 kms. or more per second. This must be due to an irresolvable companion in the star. The inclusion of these lines at present does not introduce much difference in the final result, however, probably two or three tenths of a kilometre.

When the true wave lengths of the star lines have been determined, the difference between these values and the corrected computed wave lengths gives the displacement of the lines in tenth-metres, due to the radial velocity of the star. For convenience in calculation the values of $\frac{299860}{\lambda}$ have been computed and tabulated for wave lengths of every 5 tenth-metres between $\lambda\,4175$ and $\lambda 4575$, and the velocity for any line is readily obtained by selecting the corresponding velocity for a displacement of one tenth-metre given in this table and multiplying by the displacement in the star. The mean of the values obtained for all the measured lines gives the apparent radial velocity of the star.

Correction for Curvature.

To this velocity there has to be applied a correction for curvature of the spectral lines, which causes an apparent displacement of the star lines towards the red end of the spectrum. This displacement, and its corresponding velocity value, depend upon the form of the curve taken by the line, and the distance between the centre of the star spectrum and the point on the iron spectrum where the measurement is made. The form of the curve approximates a parabola, and the equation of this parabola can be obtained either by calculation or measurement. Ditscheiner's formula as given in Frost-Scheiner Astronomical Spectroscopy gives to the parabola formed by this spectroscope the equation $x = 0{\cdot}0082\ y^2$ where x is the displacement and y the distance above

mentioned. In order to obtain the formula by measurement, two negatives of the iron spark were made, using the full length of the slit. When these negatives were placed face to face, the lines formed figures similar to equi-convex lenses, and it was easy to measure the diameter and thickness of such a lens from which the formula is easily obtained, as $x = 0{\cdot}0083\ y^2$ in almost exact agreement with that obtained by calculation. This is for the central part of the range measured, actually for the line $\lambda\,4325{\cdot}941$, but no sensible error will be introduced in using this value throughout, as the x's will be as much greater at the violet end as they are smaller at the red. In order to obtain x for any negative, all that is necessary is to measure the distance between the tips of the comparison lines or rather between the points where the measurement was made, which gives $2y$, and substitute in the above formula. When reduced to kilometres the average correction is about 0·5 km. per second, and is of the negative sign.

Reduction to Sun.

The radial velocity of the star above obtained, reduced for curvature, gives the value with respect to the observer, and to render it comparable with other determinations, three variables must be removed to obtain its velocity relative to the sun.

(*a*) Correction for the orbital velocity of the earth in its path around the sun.

(*b*) Correction for velocity of the earth caused by the revolution of the earth and moon around their common centre of gravity.

(*c*) Correction for the diurnal rotation of the earth on its axis.

Prof. W. W. Campbell has given a very complete treatment of these corrections in Astronomy and Astrophysics, and also in Frost-Scheiner's Astronomical Spectroscopy, but the calculation in the case of (*a*) has been much shortened by convenient tables, for all the brighter stars, published by Dr. Frank Schlesinger in the *Astrophysical Journal*, vol. X., p. 1. By these tables not only is the computation of the component, in the star's direction, of the velocity of the earth simplified, but the cumbrous reduction of the star's right ascension and declination to latitude and longitude is avoided. According to these tables the orbital velocity of the earth in the direction of the star is given by

$$V_a = b \sin (\odot - \lambda) + c$$

$\odot$ = longitude of the sun at the mean time of exposure,
λ = longitude of the star,
b and c are constants given along with and in the tables.

The correction (*b*) caused by the revolution of the moon around the earth is never greater than 0·01 km. per second, and so can be neglected.

The correction for the diurnal rotation of the earth is given by the formula

$$V_d = -0{\cdot}47 \sin t \cos \delta \cos \phi$$

where

t is the hour angle of the star,
δ is the declination of the star,
ϕ is the latitude of the observer.

The values of the correction for this latitude, at varying declinations and hour angles, have been computed and tabulated, from which they can be at once taken and applied to the velocity of the star with the proper sign, which is positive for stars observed east of the meridian, and negative for stars west of the meridian.

RADIAL VELOCITIES OF SELECTED STARS.

General.

The stars whose spectra have been measured and reduced for this report are certain stars of the solar type which astronomers, engaged in line of sight work, have agreed to observe periodically for radial velocities. The object of this co-operation, as

previously stated, is to obtain well determined values of the velocities of ten stars, fairly uniformly distributed in right ascension. Such stars can then serve as objects for testing the performance of the spectrograph when any of the planets or the moon are not available, and, when sufficient observations have been accumulated, the data can be used to correct the values of the wave lengths employed in the reductions. Observations are being continued now upon a number of spectroscopic binary stars, but no measurements will be included here until a sufficient number of any one star have been obtained to give a definite velocity curve and period. Seven only of the ten standard velocity stars are here given as, during the period the instrument has been giving reliable values, these were the only ones available, the other three being too close to the sun to easily obtain suitable spectra for measurement. The seven are α Boötis, β Geminorum, γ Aquilae, β Ophiuchi, α Arietis, α Persei, ϵ Pegasi. The remaining three β Leporis, γ Piscium and α Crateris, will be observed in due time and published later with probably a further determination by the new spectrograph of the whole ten stars.

The journal of observations shows the conditions prevailing during the exposures such as temperature, time and length of exposure, hour angle, focal settings, &c., and forms a complete record of all data necessary, not only for the reduction of the spectrum, but also for the comparison of different spectra in case any investigation as to temperature effects, flexure, focus, &c., may be required. The entries are made in a book, ruled in the same manner as the table below, and are thus always at hand and not likely to be mislaid or lost as might happen if they were made on separate sheets.

The measurements of the spectra are recorded and the reductions made on large pads, ruled in such a manner as to systematize the labour as much as possible and present all the data in tabular form for convenience of reference and for checking errors. Only the essential parts of these sheets are reproduced below; those which suffice to show the relation between the measures and the computed wave lengths, the corrections to the values as given by the interpolation formula, the wave lengths of the lines or blends of lines in the sun, the difference representing the displacement due to velocity, and finally, the velocity in kilometres per second for each line measured. Some idea of the accidental errors are given by the agreement of the velocities for the different lines and also by the values of the mean errors which are given below the tabular part in each reduction sheet.

It may be stated here, and it will be evident when the results are examined, that much better agreement between the lines is obtained and the mean errors are much less for the brighter stars than for those of the 3rd and 4th photographic magnitude. This is easily explained by the longer exposure required in the fainter stars, and consequent greater displacement of the lines due to temperature changes and to flexure. Although the flexure has been reduced so that the displacement produced during a two hours exposure is equivalent to a velocity of 1½ kms. per second, this displacement, with that due to variations of temperature in the outer case caused by an imperfect thermostat, is sufficient to blur the lines and prevent as accurate settings of the microscope wires as can be obtained in stars like α Boötis and β Geminorum, when the exposure is short and displacements consequently negligible. The principal effect of the flexure and temperature displacements, however, is in increasing the accidental errors, and no systematic error of any appreciable magnitude is likely to be produced owing to the compensation effected by the division of the exposure time on the comparison spectrum between the beginning and end of the exposure on the star spectrum.

RECORD OF SPECTROGRAMS.

Star.	No. of Negative.	Plate.	Date.	Middle of Exposure.	Duration.	Hour Angle at end.	Comparison Spectrum. Beginning.	Comparison Spectrum. End.	Comparison Spectrum. Kind.	Temperature. Room. Beginning.	Temperature. Room. End.	Temperature. Prism Box. Beginning.	Temperature. Prism Box. End.	Slit width.	Focal Position. Star Focus.	Focal Position. Collimator.	Focal Position. Camera.	Seeing.	Remarks.
			1906.	h. m.	m.	h. m.	s	s.		Fahr.	Fahr.	Cent.	Cent.	m.m.					
β Geminorum.	196	Seed N.H.	Feb. 22	10 27	25	1 07 W	15	15	Fe. spark.	34·4	33·6	3·8	3·7	·015	6·5	16·2	9·0	.....	
" ..	197	" ..	" 22	11 17	25	2 .. W.	23	23	" ..	33·2	32·0	3·65	3·65	·011	6·5	16·2	9·0	.....	
α Boötis	199	" .	" 22	1 37	45	2 .. E.	21	21	" ..	32·0	30·0	3·45	3·4	·011	6·5	16·2	9·0	Hazy	
β Geminorum.	212	" ..	Mar. 5	10 56	33	2 20 W.	25	25	" ..	26·5	25·0	4·5	4·5	·013	6·0	16·2	9·05	Good.	
α Boötis	216	" ..	" 5	2 42	15	0 30 E.	25	25	" .	21·5	21·3	4·4	4·2	·013	6·0	16·2	9·05	" .	
"	220	" ..	" 23	2 18	15	0 20 W.	25	25	" ..	12·8	12·2	—10·5	—10·5	·013	13·5	15·2	10·2	" .	
"	230	" .	" 28	2 15	10	0 30 W.	25	25	" ..	33·4	33·4	0·9	0·9	·015	7·5	15·2	10·2	" .	
" ..	238	Seed 27...	April 2	2 52	15	1 30 W.	30	30	" ..	32·5	32·5	7·2	7·2	·013	15·0	15·2	10·3	" .	Corr. lens 1½ in. below flange.
"	252	" ..	" 24	10 53	15	1 08 E.	20	20	" ..	47·0	46·0	11·1	11·2	·013	18·0	15·2	4·3	Fair..	Vernier placed on camera scale.
"	253	" ..	" 24	12 32	15	0 30 W.	28	28	" ..	45·0	44·6	11·2	11·3	·015	18·0	15·2	4·4	" .	
"	300	" ..	June 18	9 23	5	1 .. W.	30	30	" .	72·1	72·0	24·1	24·1	·020	18·0	15·2	5·8	.....	
"	312	" ..	" 27	8 57	7	1 05 W.	18	20	" ..	77.6	75·8	27·3	27·2	·015	18·0	15·2	5·95	Fair..	
"	319	" ..	July 2	9 19	13	1 50 W.	20	20	" ..	71·9	71·1	24·0	24·0	·017	18·0	15·2	5·95	" .	
γ Aquilae . .	323	" ..	" 2	2 10	60	1 40 W.	12	15	" ..	64·5	63·4	24·1	23·9	·025	18·0	15·2	5·95	"	
α Boötis ..	325	" ..	" 4	8 55	7	1 30 W.	20	20	" ..	63·9	63·2	21·5	21·4	·020	18·2	15·2	5·95	" .	
β Ophiuchi. ..	327	" ..	" 4	11 30	60	1 10 W.	18	18	" .	60·2	58·5	21·4	21·3	·025	18·2	15·2	5·95	Good.	
γ Aquilae	329	" ..	" 4	2 02	55	1 35 W.	15	17	" ..	56·2	55·0	21·2	21·2	·025	18·2	15·2	5·95	" .	
α Persei	330	" ..	" 4	2 48	15	5 35 E.	17	17	" ..	55·0	54·6	21·3	21·7	·025	18·2	15·2	5·95	"	
α Arietis......	331	" .	" 4	3 15	30	3 45 E.	17	17	" ..	54·5	54·2	21·6	21·3	·025	18·2	15·2	5·95	" .	
β Ophiuchi ...	334	" ..	" 6	11 25	90	2 .. W.	16	15	" ..	66·0	63·6	25·4	25·5	·025	18·2	15·2	5·95	Fair..	
γ Aquilae.. ..	335	" ..	" 6	1 25	70	1 15 W.	15	16	" ..	63·4	61·2	25·6	25·3	·025	18·2	15·2	5·95	"	
α Persei	336	" ..	" 6	2 35	20	5 35 E.	18	15	" ..	61·0	60·0	25·3	25·0	·025	18·2	15·2	5·95	" .	
α Arietis. ...	337	" ..	" 6	3 15	30	3 40 E.	18	18	" ..	60·0	59·8	24·9	24·8	·025	18·2	15·2	5·95	" .	
β Ophiuchi. ..	353	" ..	" 18	11 40	70	2 20 W.	20	20	" ..	71.0	68·7	26·3	26·4	·025	18·2	15·2	5·98	Good.	
γ Aquilae	354	" ..	" 18	1 05	80	1 45 W.	20	20	" ..	68·5	66·8	26·4	26·2	·025	18·2	15·2	5·98	" .	
"	361	" ..	Aug. 1	11 30	90	1 15 W.	20	20	" ..	72·6	69·5	27·1	27·0	·025	18·2	15·2	5·95	" .	
α Arietis.	364	" ..	" 1	2 30	45	2 35 E.	20	20	" ..	67·6	66·6	26·8	26·8	·025	18·2	15·2	5·95	" .	
ϵ Pegasi	378	Seed R. ..	" 15	11 45	40	0 05 W.	20	20	" ..	65·9	64·1	25·7	25·7	·020	18·6	15·2	5·95	" .	
α Arietis. ..	393	" ..	Sept. 10	2 05	35	0 35 E.	16	16	" ..	62·0	61·8	25·7	25·6	·025	15·0	15·2	5·75	" .	
ϵ Pegasi	400	" ..	" 27	10 42	45	1 45 W.	20	20	" ..	59·5	57·3	21·8	21·8	·025	15·0	15·2	5·62	" .	
"	409	Seed 27..	Oct. 16	10 47	45	3 05 W.	20	20	" ..	56·0	55·0	17·5	17·6	·025	18·5	15·2	5·81	" .	
α Persei	411	" ..	" 16	2 45	30	1 15 W.	20	20	" .	52·0	52·0	16·6	16·8	·025	18·5	15·2	5·81	" .	

β GEMINORUM 196.

1906. Feb. 22.
G. M. T. 15h 25m

Observed by J. S. Plaskett.
Measured by J. S. Plaskett.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W. L.	Displacement.	Velocity.
72·7488	4584·390	....	·018	......	....	49.5829	4337·148	..	·216	.....	....
71·2655	4566·198	·960	·726	·234	+15·37	48·6227	4328·373	·413	·080	·333	+23·04
69·9416	4560·270	.....	·051	......	....	47·6056	4319·186	·196	·817	·379	26·26
69.9048	4549.792	...	.642	.....	....	47·1890	4315·454	·455	·178	·277	19·22
68·7731	4536·450	·340	·965	·375	24·75	S 47·1667	4315·255	....	·255	....	....
68·1604	4529·291	·205	·807	·398	26·41	46·3545	4308 035	....	·081	......	....
68 1307	4528·945	......	·798	.....	....	45·3729	4299·401	...	·420	.....	....
67·6419	4523·278	·207	·854	·353	23·37	44·8245	4294·624	·650	·273	·377	26·31
S 65·1321	4494·754	.....	·755	......	....	44.7847	4294·275	......	·301	......	....
64·3696	4486·275	·262	·888	·374	24·98	44·1141	4288 472	·494	·134	·360	25·13
63·4919	4476·619	.592	·214	378	25.29	43·4250	4282·557		·565	....	.....
63·4571	4476·234	.....	·207	.....	....	42·5724	4275·302	·302	·922	·380	26·64
63·1910	4473·334	·317	·957	·360	24 08	40·8257	4260·661	.....	·656	......	....
62·6220	4467·158	·162	·771	·391	26·20	40·1194	4254·823	·807	·505	·302	21·29
61·9245	4459·648	·683	·304	·379	25·46	39·6918	4251·311	·290	954	·336	23·69
61·8888	4459.266	......	·301	......	....	39·6501	4250·969	......	·948	.....	....
60·8522	4448·234	·265	·892	·373	·25.10	39·2768	4247·917	·897	·566	·331	23·33
59.6431	4435·552	·580	·184	·396	26·73	39·2095	4247·370	·350	·996	·354	24·96
58·8923	4427·775	·799	·420	·379	25·65	39·0160	4245·795	·775	·455	·320	22·59
57·7084	4415·660	·680	·293	·387	26·27	38·3427	4240 358	·338	·975	·363	25·66
56·6742	4405·228	·261	·951	·310	21·08	38·2205	4239·356	·337	·970	·367	25·94
57·6668	4415.278	.....	·293	......	....	37·8611	4236·466	·447	·112	·335	23·68
56·6413	4404·895	.....	·929	.....	....	37·8198	4236·137	.....	·118	....	....
55·7019	4395·535	·575	·286	·289	19·68	36·1321	4222·721	·696	·382	·314	22·26
54·0865	4379 694	·739	·396	·343	23·46	35·7705	4219·887	·860	·520	·340	24·14
53·7409	4376·345	·405	·107	·298	20·38	35·7285	4219·551	....	·523	.....	....
53·7080	4376·028	....	·107	......	....	S 33·4867	4202·195	....	·195	.....	....
53·2510	4371·624	·689	·312	·377	25.82	33·2661	4200 510	510	·114	·396	28·40
53·0999	4370 173	·241	·856	·385	26·41	32·0510	4191·301	·281	·874	·407	29·05
52·0397	4360·069	·154	·784	·370	25·42	31·5560	4187·584	·560	·204	·356	25·49
51·3152	4353·240	330	·923	·407	28·00	31·2749	4185·483	·455	·058	·397	28·49
51·2092	4352·247	·345	·006	·339	23·32	30 5250	4179·906	·876	·542	·334	23·94
51·2655	4352·773	......	·908	......	....	30·1342	4177·019	·986	·739	·247	17·71
49.9950	4340·947	·017	·634	·383	+26·43	29·3845	4171·513	·473	·140	·333	+23 91

$s_\circ$ = 216·5922
λ = 2801·598
$\log c$ = 5·4089030

$\epsilon = \pm 2·76$
$\epsilon_\circ = \pm 0·40$

Mean... . + 24·37
V_a .. ... — 19·58
V_d ... . — ·07
Curvature — ·50 — 20·15

Radial Velocity..... + 4·2

β GEMINORUM 197

1906. Feb. 22.
G. M. T. 16^h 15^m

Observed by J. S. PLASKETT.
Measured by J. S. PLASKETT.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
72·7530	4584·228	....	·018	.....	....	49·5833	4337·157	....	·216	......	....
72·5867	4582·173	·970	·634	·336	+21·41	48·6301	4328·446	·463	·080	·383	+26·50
70·3287	4554·730	·617	·211	·406	26·72	47·6055	4319·191	·190	·817	·373	25·86
69·9462	4550·164	·064	·766	·298	19·64	47·1929	4315·495	·495	·178	·318	22·07
69·9104	4549·739	..	·642	.....	....	S 47·1660	4315·255	.....	·255	.....	....
68·7780	4536·366	·292	·965	·327	21·61	46·3541	4308·038	.....	·081	...	....
68·1670	4529·236	·174	·807	·367	24·30	45·3695	4299·376	.....	·410	......	....
68·1346	4528·859	....	.798	.....	....	44·8275	4294·650	·668	·273	·395	27·57
67·6482	4523·227	·174	·854	·320	21·22	44·7853	4294·283	....	·301	.....	....
S 65·1402	4494·755	...	·755	.....	....	44·5942	4292·626	·644	·319	·325	22·69
64·3761	4486·266	·254	·888	·366	24·45	44·1197	4288·523	·540	·134	·416	29·04
63·4925	4476·555	549	·214	·335	22·41	43·4238	4282·548	.....	·565	....	....
63·4613	4476·213	...	·207	......	....	40·1198	4254·819	·822	·505	·317	22·34
63·1975	4473·337	·338	·957	·381	25·53	39·6892	4251·281	·284	·954	·330	23·27
62·6252	4467·129	·143	·771	·372	24·96	39·6483	4250·946	....	·948	....	....
61·9300	4459·651	·683	·304	·379	25·47	39·2822	4247·953	·955	·566	·389	27·42
61·8942	4459·268	.....	·301	....	....	39·2069	4247·339	·340	·996	344	24·25
60·8546	4448·214	·253	·892	·361	24·30	39·0182	4245·802	·803	·455	·348	24·56
60·3501	4442·903	·947	·510	·437	29·45	37·8645	4236·477	·477	·112	·365	25·80
58·8937	4427·758	·807	·420	·387	26·20	37·8186	4236·119	.....	·118	...	....
57·7073	4415·626	·681	·293	·38[illegible]	26·34	37·7612	4235·672	·671	·389	·282	19·94
57·6695	4415·243	....	·293	......	....	36·1369	4222·736	·718	·382	·336	23·82
56·6759	4405·225	·250	·951	·299	20·33	35·7712	4219·860	·836	·520	·316	22·44
56·6443	4404·905	....	·929	.....	....	35·7303	4219·547	...	·523	......	....
55·7106	4395·609	·623	·286	·337	22·95	34·6165	4210·858	·846	·523	·323	22·97
54·0872	4379·695	·712	·331	·381	26·06	33·7284	4204·010	·007	·730	·277	19·75
53·7461	4376·392	·405	·107	·298	20·38	S 33·4915	4202·195	......	·195	......	....
53·7174	4376·115	.....	·107	.....	....	33·2650	4200·464	·464	·114	·350	25·03
53·2494	4371·606	·630	·312	·318	21·81	32·0511	4191·257	·257	·874	·383	27·38
53·1076	4370·245	·272	·856	·416	[illegible]8·53	31·8827	4189·989	·989	·723	·266	19·01
51·3205	4353·291	326	·923	·403	27·72	31·2691	4185·390	·390	·058	·332	23·77
51·2180	4352·330	·365	·006	·359	24·74	30·8032	4181·917	......	·918	.....	....
51·2686	4352·805	....	·908	......	....	30·5300	4179·889	·889	·542	·347	24·87
49·9978	4340·976	·012	·634	·378	+26·08	29·3875	4171·472	472	·140	·332	+23·84

$s_\circ$ = 217·4001
$\lambda_\circ$ = 2794·709
log c = 5·4130461

$\epsilon = \pm 2·67$
$\epsilon_\circ = \pm 0·38$

	Mean......	+24·61
V_a	— 19·59	
V_d	— ·14	
Curvature	— ·50	—20·23
Radial Velocity		+ 4·4

SESSIONAL PAPER No. 25a

β GEMINORUM 212.

1906. March 5.
G. M. T. $15^h\ 55^m$

Observed by J. S. PLASKETT.
Measured by J. S. PLASKETT.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
72·7745	4583·997	......	·018	. .	....	49·9935	4341·113	·112	634	478	+32·96
71·3075	4566·094	·123	·726	·397	+26·20	S 49·5701	4337·217	....	·216	....	....
70·8420	4560·487	·518	·233	·285	18·69	47·1783	4315·577	·527	·178	·347	24·12
69·9761	4550·152	·187	766	·421	27·70	47·1493	4315·318	.....	·255	......	....
69·9302	4549·607	. .	·642	......	....	44 8140	4294·770	·700	·273	·427	29·84
68·8005	4536·311	·325	·965	·360	23·80	44·7686	4294·376	....	·301	......	....
68·3908	4531·538	·543	·202	·341	22·57	44·1073	4288·661	·590	·134	·456	31·88
68 1876	4529·181	·181	·807	·374	24·75	43·4047	4282·635	.	·565	.....	....
S 68·1545	4528·797	....	·798	....	....	41·6075	4267·440	·380	·050	·330	23·20
65·1527	4494·712	......	·738	. .	.....	40·7998	4260·711	......	656	......	....
64·0772	4482.822	·835	·434	·401	26·82	39·6776	4251·463	·383	·954	·429	30·28
63·2094	4473·347	·352	·957	·395	26·46	39·5997	4250·825	·745	·287	·458	32·34
62·6357	4467 142	·140	·771	·369	24·83	39·6210	4251·033	....	·948	.....	....
62·5974	4466·730	......	·727	...	....	39·2547	4248·007	·937	·448	·489	34·47
61·9505	4459 791	·796	·304	·492	33·17	38·3244	4240·464	·418	.975	·443	31·28
58·9047	4427·881	·900	·420	·480	32.50	37·7884	4236·153	....	·118	.....	....
57·7155	4415·740	·775	·293	·482	32·73	36·1100	4222·817	·770	·382	·388	27·55
57·6682	4415·261	......	·298	...	....	35 7467	4219·962	·912	·520	·392	27·80
56·6795	4405·315	·322	·951	·371	25·27	S 33·4527	4202·197	. .	·198	.....	......
56·6402	4404·922	......	·928	...	....	33·2312	4200·504	·504	·114	·390	27·85
53·2499	4371·734	·731	·312	·419	28·75	32·0206	4191 327	·342	·874	·468	33·46
53 7051	4376 110	....	·107	......	....	31·6196	4188·313	·335	·924	·411	29·43
51·3086	4353·335	333	·923	·410	28·20	31·2474	4185·528	·555	058	·497	+35·63
51·2102	4352 415	·413	·006	·407	+28·04	30·7640	4181·926	....	·956	.....	....

$s_\circ$ = 218·6834
$\lambda_\circ$ = 2785·473
log c = 5·4189980

$\epsilon = \pm 4·16$
$\epsilon_\circ = \pm 0·72$

Mean... + 28·47
V_a ... — 24·02
V_d ...... — ·14
Curvature — ·50 — 24·66

Radial Velocity.......+ 3·8

α BOÖTIS 199.

1906. Feb. 22.
G. M. T. 18^h 35^m

Observed by J. S. Plaskett.
Measured by J. S. Plaskett.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
72·8215	4584·193	....	·018	....	....	49·6515	4337 253	....	·216	.....	....
69·9652	4549·548	·424	·766	·342	—22·53	47·6000	4318·535	·525	·817	·292	—20 27
68·7903	4535·684	·580	·965	·385	25·46	S 47·2343	4315·262	.....	·262	.....	....
68·1725	4528·481	·388	·807	·419	27·74	44·8588	4294·337	......	·301	.....	....
68·2060	4528·870	......	·798	......	....	44·8200	4294·000	·970	·273	·303	21·15
67·6648	4522·610	·525	·855	·330	21·87	42·5576	4274·609	·600	·922	·322	22·60
65·2133	4494·791	..	·738	......	....	40·8937	4260·664	.....	·656	......	....
63·4990	4475·864	·850	·214	·364	24·39	39·3728	4248·146	·135	·448	·313	22·06
63·5314	4476·218	...	·207	......	....	39·1870	4246·632	·616	·996	·380	26·83
62·6250	4466·377	·377	·771	·394	26·44	39·0928	4245·865	·846	·237	·391	27·60
S 62·6574	4466·727	...	·727	.....	....	39·0000	4245·111	·088	·455	·367	25·91
59·6441	4434·809	·826	·184	·358	24·20	38·2094	4238·714	·687	·970	·283	20·00
58·8922	4427·033	·055	·420	·365	24·71	37·8903	4236·148	.....	·118	.....	....
57·7113	4414·969	·995	·293	·298	20·24	37·7595	4235·099	·067	·389	·322	22·80
57·7357	4415·216	......	·298	......	....	35·7580	4219·234	·190	520	·330	23·46
56·6743	4404·521	·555	·951	·396	27·00	35·8006	4219·568	......	·523	......	....
56·7116	4404·894	......	·928	......	....	34·1261	4206·555	·550	·830	·280	19·96
55·7087	4394·917	·960	·286	·326	22·23	S 33·5585	4202·198	......	·195	......	....
53·7787	4376·048	...	·107	.....	....	33·2472	4199·820	·820	·114	·294	20·96
52·0352	4359·385	·410	·784	·374	25·74	30·8698	4181·917	..	·918	....	....
51·3175	4352·626	620	·923	·303	20·87	30·5130	4179·270	·270	·542	·272	—19·53
49 9838	4340·221	·192	·634	·442	—30 47						

$s_\circ$ = 217·5467
$\lambda_\circ$ = 2794·146
log c = 5·4134086

ϵ = ± 2·91
$\epsilon_\circ$ = ± 0·55

Mean.. .. — 23·59

V_a .. .... + 19·76
V_d .... + 0·11
Curvature — 0·50

+ 19·37

Radial Velocity.......— 4·2

α BOÖTIS 216.

1906. March 5.
G. M. T. $19^h\ 40^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
68·2445	4528·883	....	·798	.....	....	52·0552	4359·469	·474	·784	·310	—21·32
67·6985	4522·565	·488	·855	·367	−24·40	51·3263	4352·619	·627	·923	·296	20·39
65·2425	4494·745	....	·755	....	....	50·0096	4340·396	·406	·634	·228	15·74
64 0977	4482·078	·084	·434	·350	23·41	49·6589	4337·208	...	·216	.....	....
63·5290	4475·856	·843	·214	·371	25·43	S 47·2346	4315·255	......	·255	.....	....
63·5625	4476·221	...	·207	....	....	44·8461	4294·264	.....	·290	....	....
62·6566	4466·477	·478	·771	·293	19·67	41·8315	4268·586	·612	·888	·276	18·38
S 62 6878	4466·736	......	·737	.....	....	40·8765	4260·634	......	·656	......	....
62·4786	4464·483	484	·772	·288	19·32	39·2497	4247·285	·303	·566	·263	18·55
61·9652	4458·981	·990	·304	·314	21·11	39·1747	4246·680	·698	·996	·298	21·02
61·9942	4459·291	.....	·301	..	....	39·0838	4245·937	·954	·237	283	19·91
60·8855	4447·527	·539	892	353	23·79	38·1841	4238·673	·688	·970	·282	19·96
58·9128	4427·003	·035	·420	·385	26·06	37·8640	4236·105	.....	·118	.....	....
57·7392	4415·033	·050	·293	·243	16·50	36·6947	4222·080	·050	·382	·332	23·57
57·7600	4415·244	....	·301	...	....	35·7286	4219·211	·168	·520	·352	25·00
56 6990	4404·572	·584	·951	·367	24·95	35·7738	4219·566	....	·523	......	....
56·7312	4404·897	....	·929	......	....	S 33·5256	4202·196	.....	·195	.....	.....
55·7300	4394·946	·968	·286	·318	—21·70	33·2172	4199·845	·845	·114	·269	−19·18
53·7985	4376·101	.....	·104	....	....						

$s_\circ = 217·3159$
$\lambda_\circ = 2799·501$
$\log c = 5·4112854$

$\epsilon = \pm 2·87$
$\epsilon_\circ = \pm 0·60$

Mean.... − 21·33
V_a ...... + 16·18
V_d ..... + 0·04
Curvature — 0·46 − 15·76

Radial Velocity .... − 5·6

α[1]BOÖTIS 220.

1906. March 23.
G.M.T. $19^h\ 20^m$

Observed by J. S. Plaskett.
Measured by J. S. Plaskett.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
72·7633	4584·308	....	·018	....	......	49·6351	4337·150	.....	·216	......	....
71·2477	4565·701	·501	·726	·225	—14·70	47·1867	4314·938	·938	·178	·240	—16·68
69·9201	4549·719	·597	·766	·169	11·13	S 47·2222	4315·256	....	·255	..	....
69·9238	4549·763	..	·642	.....	....	44·8166	4294·040	·050	·273	·223	15·57
68·7520	4535·895	·789	·965	·176	11·64	44·8441	4294·279	....	·290	......	....
68·1357	4528·689	·591	·807	·216	14·30	44·1117	4287·935	·943	·134	·191	13·35
68·1535	4528·896	....	·798	......	....	42·5703	4274·759	·764	·922	·158	11·09
65·1680	4494·810	......	·738	....	....	40·8895	4260·656	....	·656	......	....
63·4685	4476·000	·920	·214	·294	19·43	39·6915	4250·765	·762	·954	·192	13·53
63·4935	4476·274	....	·185	......	...	39·2740	4247·350	·345	·566	·221	15·60
62·7826	4468·527	·500	·663	·163	10·94	39·2032	4246·773	·766	·996	·230	16·21
62·6013	4466·563	·563	·771	·208	13·96	39·1100	4246·013	·004	·237	·233	16·42
S 62·6174	4466·738	....	·737	......	....	38·2238	4238·830	·820	·970	·150	10·60
62·4288	4464·698	·700	·884	·184	12·08	37·8608	4235·909	·898	·112	·214	15·12
58·8780	4427·224	·250	·420	·170	11·51	37·8885	4236·131	.....	·118	.....	....
57·6937	4415·096	·130	·293	·163	11·16	37·7724	4235·200	·188	·389	·201	14·23
57·7096	4415·258	...	·293	...	....	36·1369	4222·196	·185	·382	·197	13·99
57·0296	4408·574	·400	·550	·150	10·20	35·7745	4219·346	·335	·520	·185	13·16
56·6656	4404·714	·732	·951	·219	14·90	35·7985	4219·534	....	·523	..	....
56·6852	4404·911	..	·929	..	....	34·1431	4206·659	·656	·830	·174	12·41
55·6940	4395·025	·040	·286	·246	16·78	S 33·5622	4202·196	.....	·195	......	....
53·7617	4376·099	...	·104	......	.....	33·2714	4199·973	·973	·114	·141	10·00
53·2457	4371·121	·126	·312	·186	12·76	32·0479	4190·692	·689	·874	·185	13·23
51·3123	4352·746	·750	·903	·153	10·54	30·8763	4181·923	.....	·918	...	....
51·2077	4351·764	·769	·006	·237	16·32	30·5355	4179·396	·391	·523	·132	—9·47
49·9958	4340·478	·483	·634	·151	—10·43						

$s_0 = 216{\cdot}4974$
$\lambda_0 = 2801{\cdot}149$
$\log c = 5{\cdot}4087498$

$\epsilon = \pm\ 2{\cdot}45$
$\epsilon_0 = \pm\ 0{\cdot}42$

	Mean......	−13·33
V_a	+ 9·24	
V_d	0·00	
Curvature..	− 0·50	+ 8·74
Radial Velocity		− 4·6

α BOOTIS 230.

1906. March 28. Observed by J. S. PLASKETT.
G. M. T. 19h 15m Measured by J. S. PLASKETT.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
72·815	4584·219	.....	·018	.....	....	49·999	4340·447	·480	·634	·154	−10·64
70·210	4552·542	·435	·594	·159	− 10·47	49·640	4337·144	.....	·216	.....	....
69·972	4549·703	·606	·766	·160	10·54	49·168	4332 823	·850	·988	·138	9 55
69·975	4549 739	.....	·642	.....	....	47·186	4314·943	·943	·178	·235	16·33
68·804	4535·908	·823	·965	·142	9·38	S 47 221	4315·255	...	·255	.....	....
68·185	4528 684	·623	·807	·184	12·18	44·811	4294·059	·080	·273	·193	13·47
68·200	4528·859	.....	·798	.....	....	44·833	4294·247	.....	·290	.....	....
64·074	4482·204	·188	·434	·246	16·16	42·558	4274·776	·800	·922	·122	8·56
61·950	4459·157	·151	·304	·153	10·28	41·739	4267·890	·900	·035	·135	9·48
61·964	4459·308	.....	·301	.....	....	40 871	4260·661	.....	·656	.....	....
S 62·655	4466·737	.....	·737	.....	....	40·588	4258·320	·320	·477	·157	11·05
60·868	4447·660	·676	·892	·216	14 55	40·103	4254·325	·325	·505	·180	12·69
60·356	4442·274	·294	·510	·216	14·60	39.672	4250·793	·793	·954	·161	11.35
58·906	4427·213	·243	·420	·177	11·98	39·261	4247·441	·441	·566	·125	8·82
57·720	4415·097	·130	·293	·163	11·06	39·183	4246·807	·808	·996	·188	13·27
57·735	4415·249	.....	·301	.....	....	38·322	4239·841	·842	·975	·133	9·41
57·056	4408·394	·429	·550	·121	8·23	37·839	4235·963	·965	·112	·147	10·39
56·688	4404·701	·737	·951	·213	14·48	37 858	4236·115	.....	·118	.....	....
56·707	4404·892	.....	·929	.....	....	35·743	4219·374	·360	·520	·160	11·38
55·718	4395·052	·090	·286	·196	13·37	35·765	4219·546	.....	·523	.....	....
55·191	4389·859	·900	·105	·205	14·00	34·111	4206·722	·715	·830	·115	8·20
54·098	4379·194	·236	·396	·160	10·95	S 33 520	4202·195	....	·195	.....	....
53·756	4375·887	·930	·107	·177	12·12	33·235	4200·022	·020	·114	·094	6·72
53 774	4376·061	...	·104	.....	....	32 005	4190·724	·718	·874	·156	11·17
52·045	4359·546	·590	·784	·194	13·34	30·826	4181·927	.....	·918	.....	....
51·325	4352·772	·810	923	·113	7·78	30·492	4179·455	·440	·542	·102	− 7·31
51·221	4351 797	·830	·006	·176	−11·92						

$s_0 = 216·484$
$\lambda_0 = 2805·448$
$\log c = 5·4074833$

$\epsilon = \pm 2·39$
$\epsilon_0 = \pm 0·39$

Mean .... − 11·27

V_a .... + 7·13
V_d .... − 0·04
Curvature — 0·50 + 6·59

Radial Velocity...... − 4·7

α BOOTIS 238

1906. April 2,
G. M. T. 19h 50m

Observed by J. S. PLASKETT.
Measured by J. S. PLASKETT.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
72·856	4584·340	....	·018	......	....	47·832	4320·739	·780	·992	·212	−14·71
71·341	4565·798	·560	·726	·166	−10·92	47·186	4314·962	·962	·178	·216	15·01
70·006	4549·776	......	·642	..	....	S 47·2185	4315·255	......	·255	....	....
68·835	4535·961	·850	·965	·115	7·60	44·811	4294·108	·160	·273	·113	7·89
68·218	4528·770	·670	·807	·137	9·08	44·826	4294·238	......	·290	...	....
68·229	4528·897	.....	·798	....	....	42·550	4274·784	·824	·922	·098	6·88
65·231	4494·784	...	·755	.....	....	40·855	4260·624	....	·656	...	....
64·103	4482·296	·280	·434	·154	10·30	40·094	4254·355	·380	·505	·125	8·81
S 62·6735	4466·737	.....	·737	......	....	39·659	4250·795	·814	·954	·140	9·87
61·557	4454·778	790	·962	·172	11·57	39·356	4248·327	·341	·448	·104	7·34
58·925	4427·264	·300	·420	·120	8·12	39·241	4247·392	·408	·566	·158	11·13
57·735	4415·124	·175	·293	·118	8·01	39·169	4246·807	·819	·996	·177	12·49
57·745	4415·225	....	·301	..	....	38·307	4239·844	·849	·975	·126	8·90
57·067	4408·392	·445	550	·105	7·14	37·822	4235·956	·958	·112	·154	10·88
56·700	4404·711	·768	·951	·183	12·44	37·842	4236·116	...	·118	......	....
56·716	4404·871	... .	·929	...	....	36·086	4222·210	·185	·382	·197	13·99
55·730	4395·074	·118	·286	·168	11·46	35·729	4219·416	·383	520	·137	9·74
53·785	4376·098	.....	·104	......	....	35·747	4219·556	....	·523	......	....
53·270	4371·149	·199	·312	·113	7·68	S 33·4967	4202·195	......	·195	......	....
53·114	4369·660	·710	·856	·146	10·01	33·214	4200·034	·032	·114	·082	5·78
52·051	4359·558	·608	·784	·176	12·11	31·213	4185·000	·982	·058	·076	5·45
51·330	4352·783	·833	·923	·090	6·20	30·800	4181·936	......	·918	......	....
51·220	4351·755	·805	·006	·201	13·84	30·466	4179·468	·450	·523	·073	5·24
50·003	4340·467	·517	·634	·117	−8·08	29·553	4172·767	·755	·883	·128	9·20
49·634	4337·077	.....	·216	..	....	29·316	4171·039	·010	·140	·130	−9·35

s_o = 216·573
λ_o = 2806·810
log c = 5·4073251

$\epsilon = \pm 2·63$
$\epsilon_o = \pm 0·44$

Mean..... − 9·62
V_a .... + 5·07
V_d .... − ·11
Curvature. − ·50 + 4·46

Radial Velocity...... − 5·2

α BOÖTIS 252.

1906. April 24. G. M. T. $15^h\ 55^m$

Observed by J. S. PLASKETT.
Measured by J. S. PLASKETT.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
68·8622	4536·063	·980	·965	·015	+1·00	53·1215	4369·887	·887	·856	·031	+2·13
68·6340	4533·402	·325	·349	·021	—1·39	51·3262	4352·936	·936	·923	·013	+0·89
68·3267	4529·832	·756	·784	·028	—1·85	49·9981	4340·630	·630	·634	·004	—0·28
68·2440	4528·874	·803	·807	·004	—0·27	49·6240	4337·199	·199	·216	·017	—1·17
68·2435	4528·869	.....	·798	.....	.....	S 48·3848	4325·941	.....	·941	.....	.....
67·7256	4522·893	·825	·855	·030	—1·99	47·5942	4318·845	·845	·817	·028	+1·94
64·1233	4482·442	·422	·434	·012	—0·80	47·1771	4315·128	·120	·178	·058	—4·03
63·5502	4476·182	·170	·214	·044	—2·94	47·1938	4315·277	.....	255	.....	.....
63·5602	4476·291	.....	·207	.....	.....	44·7979	4294·268	·268	·273	·005	—0·35
63·2598	4473·027	·019	·957	·042	+2·82	44·8003	4294·289	.....	·290	.....	.....
62·6810	4466·775	·775	·771	·004	+0·27	42·5350	4274·954	·954	·922	·032	+2·25
S 62·6775	4466·738	.....	·737	.....	.....	41·8106	4268·877	·877	·888	·011	—0·77
61·9827	4459·294	·296	·304	·008	—0·54	40·8208	4260·653	.....	·656	.....	.....
59·7462	4435·780	·785	·851	·065	—4·39	39·5587	4250·300	·300	·287	·013	+0·92
58·9305	4427·369	·377	·420	·043	—2·91	39·2266	4247·601	·601	·566	·035	+2·47
57·7471	4415·320	·332	·293	·039	+2·65	38·9594	4245·436	·436	·455	·019	—1·34
57·7440	4415·289	.....	·301	.....	.....	37·7925	4236·055	·055	·112	·057	—4·02
57·0772	4408·578	·593	·550	·043	+2·93	37·8002	4236·117	.....	·118	.....	.....
57·0036	4407·841	·855	·851	·004	+0·27	36·0615	4222·365	·365	·382	·017	—1·21
56·8982	4406·786	·800	·810	·010	—0·68	35·6994	4219·535	·535	·520	·015	+1·07
56·7053	4404·860	·880	·951	·071	—4·82	35·7051	4219·579	.....	·523	.....	.....
56·7102	4404·908	.....	·929	.....	.....	33·4496	4202·195	.....	·195	.....	.....
55·7335	4395·223	·240	·286	·046	—3·14	31·1717	4185·066	·066	·058	·008	+0·57
54·5583	4383·723	.....	·724	.....	.....	30·7466	4181·916	.....	·918	.....	.....
54·1102	4379·382	·382	·396	·014	—0·96	29·8175	4175·080	·080	·110	·030	—2·15
53·7646	4376·051	·051	·107	·056	—3·84						

$s_\circ = 217·3804$
$\lambda_\circ = 2801·977$
$\log c = 5·4108502$

$\epsilon = \pm\ 2·17$
$\epsilon_\circ = \pm\ 0·36$

	Mean...	—0·64
V_a ... — 4·50		
V_d ...... + 0·10		
Curvature — 0·50		—4·90
Radial Velocity		— 5·5

α BOÖTIS 253.

1906. April 24.
G. M. T. $17^h\ 30^m$

Observed by J, S. Plaskett.
Measured by J. S. Plaskett.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
68·8761	4536·080	·030	·965	·065	+ 4·30	53·7767	4376·142	·145	·107	·038	+ 2·60
68·6478	4533·381	·345	·349	·004	— 0·26	53·1259	4369·908	·910	·856	·054	+ 3·70
68·2536	4528·848	·820	·807	·013	+ 0·85	51·3321	4352·978	·980	·923	·057	+ 3·90
68·2516	4528·825	......	·798	. .	....	50·0002	4340·641	·643	·634	·009	+ 0·62
67·7406	4522·933	·900	·855	·045	+ 2·98	49·6280	4337·229	·230	·216	·014	+ 0·97
65·2444	4494·723	......	·755	.....	....	S 48·3850	4325·941	.....	941	......	....
64·1330	4482·452	·425	·434	·009	— 0·60	47·8299	4320·954	·940	·992	·052	— 3·60
63·5652	4476·253	·230	·214	·016	+ 1·07	47·1836	4315·188	·148	·178	·030	— 2·08
63·5630	4476·230	...	·207	. .	....	47·1965	4315·303	......	·255	.. ..	....
62·6932	4466·822	·822	·771	·051	+ 3·42	44·7991	4294·288	·260	·273	·013	— 0·91
S 62·6850	4466·734	...	737	.....	....	44·8024	4294·317	......	·290	......	....
58·9405	4427·417	·420	·420	·000	0·00	41·7156	4268·100	·074	·035	·039	+ 2·74
57·7546	4415·348	·355	·293	·062	+ 4·21	40·8215	4260·678	......	·656	.. .	....
57·7492	4415·293	.. .	·301	.....	....	39·2276	4247·630	·610	·566	·044	+ 3·10
57·0861	4408·623	·633	·550	·083	+ 5·64	39·1535	4247·030	·010	·996	·014	+ 0·98
57·0096	4407·857	·870	·851	·019	+ 1·30	38·2852	4240·025	·998	·975	·023	+ 1·62
56·7149	4404·913	.....	·929	.. .	....	35·7043	4219·600	·585	·520	·065	+ 4·62
56·7160	4404·924	·938	·951	·013	— 0·88	35·6965	4219·539	.....	·523	.. ..	....
56·3865	4401·645	·652	·589	·063	+ 4·28	S 33·4458	4202·195	.....	·195	.....	....
55·7445	4395·295	·301	·286	·015	+ 1·02	31·9514	4190·912	·910	·874	·036	+ 2·58
54·5608	4383·718	...	·724	......	....	30·7433	4181·922	......	·918	....	....
54·1140	4379·392	·395	·396	.. .	0·00	30·4312	4179·618	·612	·542	·070	+ 5·02

s_o = 217 7153
λ_o = 2799·574
log c = 5·4123938

$\epsilon = \pm$ 2·25
$\epsilon_o = \pm$ 0·41

	Mean... ..	+ 1·77
V_a.......	— 4·58	
V_d.... .	— 0·04	
Curvature	— 0·50	— 5·12
Radial Velocity		— 3·4

α BOÖTIS 300.

1906. June 18
G. M. T. $14^h 25^m$

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings. (A)	Computed Wave Length. (A)	Corrected W. L. (A)	Normal W. L. (A)	Displacement. (A)	Velocity. (A)	Mean of Settings. (B)	Computed Wave Length. (B)	Corrected W. L. (B)	Normal W. L. (B)	Displacement. (B)	Velocity. (B)
68·9018	4536·317	·297	·965	·332	+21·94	49·6279	4337·447	·456	·216	·240	+ 16·58
68·2785	4529·086	·076	·807	·269	17·80	S 48·3593	4325.941	....	·941	....	....
68·2555	4528·820	..	·798	....	....	47·8294	4321·185	·181	·907	·274	18·98
67·7685	4523·214	·194	·855	·339	22·47	47·5954	4319·094	·089	·817	·272	18·84
65·2475	4494·762	....	·755	....	....	47·1786	4315·384	·379	·178	·201	13·96
64·1535	4482·709	·710	·434	·276	18·45	47·1664	4315·277	....	·255	....	....
S 63·5573	4476 205	....	·207	....	....	44·7978	4294·537	·503	·273	·230	16·05
62·7055	4467·007	·007	·771	·236	15·83	44·7736	4294·328	....	·290	....	....
62·6817	4466·751	....	·737	....	....	42·5271	4275·214	·194	·922	·272	19·06
62·0052	4459·520	508	·304	·204	13·70	41·8012	4269·096	·086	·888	·198	13·89
61·6045	4455·266	·254	·962	·292	19·65	40·7833	4260·650	....	·656	....	....
58·9537	4427·662	·674	·420	·254	17·19	40·5515	4258·740	·746	·477	·269	18·93
57·7587	4415·517	·547	·293	·254	17·19	39·6316	4251·209	·211	·954	·257	18·11
57·7342	4415·269	....	·301	....	....	39·2131	4247·809	·812	·566	·246	17·34
57·0962	4408·860	·870	·550	320	21·76	39·1386	4247·197	·200	·996	·204	14·38
57·0194	4408·093	·103	·851	·252	17·13	38·9496	4245.675	·670	·455	·215	15·17
56·7016	4404·922	....	·929	....	....	38·2761	4240·252	·244	·975	·269	19·01
55·7511	4395·513	·525	·286	·239	16·29	37·7896	4236·360	·353	·112	·241	17·03
54·5411	4383·706	....	·724	....	....	37·7603	4236·127	....	·118	....	....
54·1234	4379·655	·670	·396	·274	18·74	36·0537	4222·642	·634	·382	·252	17·89
53·2821	4371·580	·594	·312	·282	22·05	35·6857	4219·767	·761	·520	·241	17·11
51·9567	4359·027	·032	·732	·300	20·61	S 33·4034	4202·195	....	·195	....	....
51·3380	4353·236	·247	·923	·324	22·97	33·1641	4200·377	·377	·114	·263	18·75
50·0025	4340·879	.889	·634	·255	+ 17·59	30·4072	4179·773	·773	·542	·231	+16·56

$s_\circ$ = 218·2261
$\lambda_\circ$ = 2796·707
$\log c$ = 5·4145824

$\epsilon = \pm 2·41$
$\epsilon_0 = \pm 0·41$

Mean.......... + 17·95
V_a .... — 22·55
V_d .... – 0·07
Curvature — 0·46
— 23·08

Radial Velocity........— 5 1

α BOÖTIS 312.

1906. June 27.
G.M.T. 14h 0m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
68·9161	4536·195	·265	·965	·300	+19·83	S 48·3616	4325·941	......	·941	....	......
68·3002	4529·021	·101	·807	·294	19·46	47·1843	4315·246	·378	·178	·200	+ 13·90
68·2736	4528·715	......	·798	......	....	47·1715	4315·313	......	·255	......	....
67·7877	4523·131	·209	·855	·354	23·47	44·7963	4294·536	500	·273	·227	15·84
65·2656	4494·708	....	·755	.....	....	41·7074	4268·349	·332	·035	·297	20·84
64·1751	4482·706	·729	·434	·295	19·73	40·7809	4260 673	....	·656	......	......
63·5762	4476·187	......	·207	......	....	39·6320	4251·263	·248	·954	·294	20·72
S 62·6999	4466·737	..	·737	......	....	39·3270	4248·786	·774	·448	·326	22·98
58·9697	4427·675	·715	·420	·295	19·97	39·2168	4247·893	·882	·566	·316	22·27
57·7722	4415·531	·586	·293	·293	19·89	38·9482	4245·720	·711	·455	·256	18·07
57·7450	4415·245	. .	·301	......	....	38·2745	4240·301	·297	·975	·322	22·76
57·1018	4408·794	·847	·550	·297	20·19	37·7808	4236·353	·353	·112	·241	17·06
54·5492	4383·683	....	·724	.. ..	....	37·7525	4236·128	......	·127	......	......
53·7903	4376·368	·408	·107	·301	20·58	36·0429	4222·632	·632	·382	·250	17·75
51·3451	4353·249	·272	·923	·349	24·01	S 33·3917	4202·195	......	·195	......	....
51·2366	4352·239	·262	·006	·256	17·66	30·3850	4179·713	·773	·542	·231	+16·56
50·0153	4340·957	·960	·634	·326	+ 22·49	29·6728	4174·492	.... .	·659	.... .	....

s_o = 218·6778
λ_o = 2794·301
log c = 5·4164126

ϵ = ± 2·64
ϵ_c = ± 0·56

Mean.......... +19·82
V_a ... . −24·00
V_d .. .. . − 0·09
Curvature. − 0·46
−24·55

Radial Velocity .... − 4·7

α BOÖTIS 319.

1906. July 2.
G. M. T. 14h 20m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
68·9275	4536·133	·273	·965	·308	+ 20·32	51·2682	4352·353	·306	·006	·300	+ 20·67
68·3053	4528·928	·078	·807	·271	17·94	50·4569	4344·832	·830	·597	·233	16·07
68·2800	4528·636	......	·798	.....	....	S 48·3841	4325·941	......	·941	.....	....
67·7952	4523 066	·166	·855	·311	20·61	47·6343	4319·220	·159	·817	·342	23·76
65·2758	4494·678	. ....	·755	...	....	47·1935	4315·297	....	·255	......	.. ..
63·6168	4476·486	·486	·214	·272	18·19	44·8325	4294·616	·573	·273	·300	20·94
S 63·5910	4476·210	......	·207	. ..	....	42·5657	4275·280	·230	·922	·308	21·56
62·9963	4469·781	·809	·520	·289	19·36	40·8200	4260·718	.....	·656	.....	....
62·7086	4466·690	.. ..	·737	.....	....	39·6727	4251·311	·261	·954	·307	21·64
62·0433	4459·586	·601	·304	·297	19·95	39·3722	4248·866	·816	·448	·368	25·94
61·6333	4455·238	·262	·962	·300	20·19	39·2602	4247·957	·907	·566	·341	24·04
58·9892	4427·730	·750	·420	·330	22·34	38·3182	4240·353	·313	·975	·338	23·82
57·7962	4415·612	·622	·293	·329	22·30	37·8272	4236·421	·396	·112	·284	20·07
57·7601	4415·248	..	·301	......	....	36·0940	4222·707	·687	·382	·305	21·62
57·1226	4408·849	·857	·550	·307	20·87	S 33·4385	4262·194	....	·195	......	......
56·7348	4404·982	......	·929	....	....	33·2004	4200·383	·393	·114	·279	19·89
55·7915	4395·648	·598	·286	·312	21·27	30·4460	4179·768	·788	·523	·265	19·00
52·1057	4360·193	·143	·784	·359	24·66	29·8402	4175·314	·344	·110	·234	+ 16·77
51·3717	4353·317	·267	·923	·334	+ 22·97						

s_o = 219·4785
λ_o = 2785·562
log c = 5·4208635

ϵ = ± 2·33
ϵ_c = ± 0·45

Mean........ + 20·24
V_a ... . — 24·52
V_d .... — 0·14
Curvature — 0·46
— 25·12

Radial Velocity... ....— 4·9

α BOOTIS 325.

1906. July 4. Observed by J. S. Plaskett.
G. M. T. $13^h\ 55^m$. Measured by J. S. Plaskett.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
68·8850	4536·408	·268	·965	·303	+ 20·02	53·2899	4371·683	·688	·312	·376	+ 25·75
68·4745	4531·628	·518	·202	·316	20·88	53·1367	4370·222	·227	·856	·371	25·45
68·2654	4529·204	·094	·807	·287	19·66	52·0664	4360·078	·083	·784	·299	20·54
68·2399	4528·909	...	·798	...	...	51·3401	4353·266	·271	·923	·348	23·94
67·7505	4523·263	190	·855	·335	22·21	51·2346	4352·286	·291	·006	·285	19·60
S 65·2291	4494·754	...	·755	...	...	50·0121	4340·974	·979	·634	·345	23·80
64·1472	4482·810	·800	·434	366	24·31	S 48·3592	4325·942	...	·941	...	...
63·5447	4476·230	...	·207	...	...	47·6046	4319·177	·184	·817	·367	23·38
63·2741	4473·293	·281	·957	·324	21·70	47·1813	4315·407	·414	·178	·236	16·37
62·7028	4467·124	·110	·771	·339	22·71	47·1638	4315·252	...	255	...	...
62·6702	4466·773	...	·737	...	...	44·8027	4294·575	·580	·273	·307	21·42
62·0043	4459·643	·628	·304	·324	21·77	44·7705	4294·297	...	·290	...	...
59·7084	4435·523	·508	·184	·324	21·90	42·5381	4275·268	268	·922	·346	24·25
58·9507	4427·718	·706	·420	·286	19 36	40·7839	4260·654	...	·656	...	...
57·7657	4415·658	·648	·293	·355	24·10	39·0576	4246·553	·540	·237	·303	21·39
57·7302	4415·300	...	·301	...	...	38·9597	4245·762	·749	·455	·294	20·75
57·0929	4408·890	·880	·550	·330	22·44	38 2855	4240·335	·322	·975	·347	24·53
56 7220	4405·185	·180	·951	·229	15·57	37·7072	4235·713	·700	·389	·311	21·98
56·6982	4404·946	...	·929	...	...	35·6968	4219·873	·863	·520	·343	24·35
55·7514	4395·565	·565	·286	·279	19·70	35·6555	4219·551	...	·523	...	...
54·5411	4383·732	...	·724	...	...	S 33·3992	4202·19[illegible]	...	·195	...	...
54·1248	4379·703	·706	·396	·310	+ 21·20	30·4134	4179·872	·879	·542	·337	+ 24·16

$s_\circ$ = 216·9934
$\lambda_\circ$ = 2807·280
log c = 5·4084067

ϵ = ± 2·40
$\epsilon_\circ$ = ± 0·42

Mean .. + 21·90
V_a ..... — 24·69
V_d ..... — 0·11
Curvature — 0·46
—25·26

Radial Velocity...... — 3·4

α BOÖTIS 325

1906. July 4
G. M. T. 13ʰ 55ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
70·0230	4549·578	..	·642	......	......	54·1358	4379·711	·706	·396	·310	+ 21·20
68·8939	4536·309	·345	·965	·380	+25·11	53·7883	4376·364	·354	·107	·247	16·89
68·2762	4529·132	·157	·807	·350	23·17	53·3015	4371·699	·689	·312	·377	25·82
68·2456	4528·778	....	·798	......	......	53·1466	4370·220	·210	·856	·354	24·28
67·7622	4523·207	·235	·855	·380	25·19	52·0740	4360·057	·047	·784	·263	18·06
65·2392	4494·702	......	·755	......	......	51·3511	4353·282	·273	·923	·350	24·08
64·1565	4482·756	·781	·434	·347	23·21	51·2478	4352·319	·309	·006	·303	20·84
63·2802	4473·211	·221	·957	·264	17·68	50·0192	4340·951	·914	·634	·310	21·39
62·9723	4469·883	·890	·520	·370	24·82	S 48·3687	4325·941	.....	·941	......	......
62·7153	4467·114	·114	771	·343	23·01	47·1950	4315·444	·444	·178	·266	18·48
S 62·6801	4466·737	......	·737	......	......	46·3626	4308·086	.....	·081	......	......
62·0136	4459·605	·600	·304	·296	19·89	44·8085	4294·539	·543	·273	·270	18·84
60·9390	4448·233	·223	·892	·331	22·27	42·5507	4275·287	·297	·922	·375	26·28
58·9621	4427·716	·716	·420	·296	20·71	40·7927	4260·636	.....	·656	......	......
57·7405	4415·291	.	·301	......	......	38·9650	4245·712	·725	·455	·270	19·06
57·1052	4408·905	·905	·550	·355	24·14	38·2939	4240·308	·325	·975	·350	24·74
56·7073	4404·931	....	929	.....	......	35·7035	4219·823	·830	·520	·310	+22·01
55·7606	4395·553	·553	·286	·267	+ 18·89	S 33·4136	4202·195	.. ..	·195	...	......

$s_\circ$ = 217·5645
$\lambda_\circ$ = 2802·185
log c = 5·4113050

ϵ = ± 2·80
$\epsilon_\circ$ = ± 0·54

Mean.... +21·91
V_a .... — 24·69
V_d .... — 0·11
Curvature.. — 0·46 —25·26

Radial Velocity ..... — 3 3

γ AQUILAE 323.

1906. July 2.
G. M. T. 19ʰ 10ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
70·4754	4554·043	·063	·211	·148	− 9·73	58·9964	4427·346	·320	·420	·100	− 6·77
70·0992	4549·578	·598	·766	·168	10·54	57·8015	4415·204	.....	·301	.. .	......
70·0948	4549·526	....	·642	......	......	57·4977	4412·146	·130	·200	·070	4·75
68·9211	4535·742	·754	·965	·211	13·94	56·7777	4404·955	.....	·929	......	......
68·5073	4530·935	·945	·202	·257	17·01	55·7813	4395·083	·078	·286	·208	14·18
S 68·3226	4528·798	....	·798	......	......	S 54·6181	4383·724	....	·724	......	......
68·3107	4528·660	·660	·807	·147	9·73	53·3232	4371·268	·268	·312	·044	3·01
67·8020	4522·801	·805	·855	·050	3·33	49·3102	4333·884	·889	·925	·036	2·49
65·3177	4494·754	....	·755	......	......	49·1830	4332·728	·733	·988	·255	−17·64
64·1909	4482·331	·316	·434	·118	− 7·89	S 48·4322	4325·941	.....	·941	......	......
62·7553	4466·768	..	·737	.....	......						

$s_\circ$ = 217·5952
$\lambda_\circ$ = 2803·551
log c = 5·4108313

ϵ = ± 5·29
$\epsilon_\circ$ = ± 1·46

Mean .. . − 9·31
V_a .... + 8·23
V_d .... − 0·09
Curvature.. − 0·46 + 7·68

Radial Velocity ... − 1·6

γ AQUILAE 323

1906, July 2.
G. M. T. 19ʰ 10ᵐ

Observed by J. S. Plaskett.
Measured by J. S. Plaskett.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
S 68·2611	4528·798	......	·798	...	....	57·4363	4412 099	·109	·200	·091	6·17
68·2486	4528·654	·644	·807	·163	– 10·79	S 56·7195	4404 928	...	·929		....
67·7407	4522·800	·790	·855	·065	4·30	55·7213	4395·048	·068	·286	·218	14·86
65·2591	4494·764		·755	.....	....	54·5544	4383 654	....	·724	..	....
63·5590	4476·081	066	·214	·148	9·90	54·1011	4379·272	·307	·396	·089	6·08
63·5747	4476·251	..	·207	. .	......	53·2611	4371·214	·254	·312	·058	3·97
63·2562	4472·797	·777	·957	·180	12·06	48·3706	4325·903	..	·941	....	....
62·8556	4468·472	·457	·663	·206	13·80	45·3826	4299·491	. ..	·420	. . .	....
62·6865	4466·653	·638	·771	·133	8·92	S 43·4116	4282·567	....	·567	....	....
62·6911	4466·702	......	·737	..	....	41·5536	4256·961	·901	·122	·221	15·53
58·9322	4427·273	·273	·420	·147	– 9·95	40·5218	4258·431	·341	·477	·136	– 9·57
57·7439	4415·196	. ..	·301	....	......	40·8046	4260 764	......	·656	. . .	....

$s_o = 216·8339$
$\lambda_o = 2810·371$
$\log c = 5·4070705$

$\epsilon = \pm 3·79$
$\epsilon_o = \pm 1·05$

Mean...... – 9·69
V_a .... + 8 23
V_d ....— 0·09
Curvature.. — 0·50 + 7·64

Radial Velocity...... – 2·0

γ AQUILAE 329.

1906. July 4.
G. M. T. 19ʰ 0ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
S 72·8207	4584·018	.	018	.....	....	60·8212	4447·711	·701	·892	·191	– 12 85
70·3446	4554·079	·159	·211	·054	— 4·86	58·8533	4427·313	·300	·420	·120	8·12
70·2097	4552·477	·560	·594	·034	2·23	57·6651	4415·244	. ..	·293	.. ..	....
68·3800	4531·030	·115	·202	·087	5·75	57·3560	4412·122	·120	·200	080	5·43
68·1787	4528·703	...	·798	. .	....	56·6385	4404·956	....	·927	....	....
68·1689	4528·589	·674	·807	·133	8·80	54·0072	4379·175	·163	·396	·233	15·95
67·6579	4522·709	·789	855	·066	4·37	53·1697	4371·141	·131	·312	·181	12·41
65·1750	4494·697	....	·738	....	....	S 48·2932	4325·939	. .	·939	.....	....
63·4927	4476·229	. ..	·185	....	.. ..	44·7005	4294·262	....	·301	.. .	....
63·1734	4472·769	·779	·957	·178	11·92	40·7184	4260·649	..	·656	.....	....
S 62·6128	4466·727	....	·727	....	. ...	38·1729	4239·942	·920	·975	·055	– 3·88
62·6032	4466·625	·625	·771	·146	– 9·79						

$s_o = 218·2530$
$\lambda_o = 2795·704$
$\log c = 5·4151044$

$\epsilon = \pm 4·17$
$\epsilon_o = \pm 1·20$

Mean...... – 8·18
V .... . . + 7·47
V_d .... — 0 09
Curvature.. — 0·50 + 6·88

Radial Velocity.... – 1·3

γ AQUILAE 335.

1906. July 6.
G. M. T. $18^h\ 25^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
S 68·3458	4528·798	....	·798	....	......	57·5045	4412·153	·133	·200	·067	−4·54
68·3310	4528·630	·630	·807	·177	−11·71	S 56·7811	4404·927	....	·927	....	......
67·8220	4522·775	·765	·855	·090	5·96	54·6240	4383·752	....	·720	....	......
65·3382	4494·784	....	·738	....	......	54·1608	4379·280	·280	·396	·116	7·93
63·6429	4476·194	....	·185	....	......	53·3246	4371·266	·266	·312	·046	3·15
63·3292	4472·798	·768	·957	·189	12·66	49·1909	4332·813	·833	·988	·155	10·72
62·7681	4466·760	....	·727	....	......	S 48·4299	4325·939	....	·939	....	......
62·7600	4466·672	·642	·771	·129	8·65	47·8642	4320·867	·887	·992	·105	−7·27
59·0061	4427·364	330	·420	·090	− 6·77	46·4197	4308·068	..	·081	....	......
57·8065	4415·190	....	·293	....	......						

s_o = 218·6983
λ_o = 2794·480
log c = 5·4162390

$\epsilon = \pm 3·07$
$\epsilon_o = \pm 0·96$

Mean...... − 7·94
V .... + 6·66
V_d .... − 0·04
Curvature.. − 0·46 + 6·16

Radial Velocity...... − 1·8

γ AQUILAE 351.

1906. July 18.
G. M. T. $18^h\ 05^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
73·1626	4586·127	·127	·163	·036	−2·35	63·3175	4472·932	·897	·957	·060	−4·02
S 72·9902	4584·017	....	·018	....	......	62·7455	4466·782	....	·727	....	......
70·5007	4554·081	·131	·211	·080	−5·26	62·7467	4466·796	·751	·771	·020	−1·34
70·3653	4552·480	·530	·594	·064	−4·21	58·9971	4427·548	·468	·420	·048	+3·24
70·1201	4549·589	....	·642	....	......	57·7970	4415·363	....	·293	....	......
70·1214	4549·606	·656	·766	·110	−7·04	56·7734	4405·109	....	·927	....	......
68·9489	4535·908	·945	·965	·020	−1·32	54·6011	4383·761	....	·720	....	......
68·5322	4531·091	·131	·202	·071	−4·70	54·1486	4379·383	·338	·396	·058	−3·96
68·3307	4528·771	....	·798	....	......	53·3098	4371·330	·295	·312	·017	−1·16
67·8057	4522·754	·779	·855	·076	−5·03	S 48·4217	4325·938	....	·939	....	......
S 65·3135	4494·738	....	·738	....	......						

s_o = 222·9795
λ_o = 2750·386
log c = 5·4393723

$\epsilon = \pm 2·69$
$\epsilon_o = \pm 0·77$

Mean. ... − 3·10
V_a .... + 1·63
V_d ... − 0·15
Curvature. − 0·46 − 1·02

Radial Velocity..... − 2·1

γ AQUILAE 361.

1906. Aug. 1. Observed by W. E. HARPER.
G. M. T. $16^h\ 30^m$ Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
73·0271	4584·112	.....	·018	.....	....	*58·9070	4425·956	966	·608	.....	....
69·0022	4535·993	·923	·965	·042	− 3·43	57·8524	4415·258	....	293	....	....
68·5867	4528·863	.....	·798	....	....	S 56·8207	4404·927	......	·927	.....	....
68·3847	4528·840	·780	·807	·027	− 1·78	54·6641	4383·747	..	·720	..	....
67·8801	4523·036	·976	·855	·121	+ 8·02	54·2231	4379·485	·455	·396	·059	+ 4·03
63·6917	4476·326	·300	·214	·086	+ 5·75	53·3867	4371·463	·423	·312	·111	+ 7·60
S 65·3700	4494·738	....	·738	......	....	52·1602	4359·845	·815	·784	·031	+ 2·12
63·6852	4476·256	......	·185	...	....	51·1358	4353·063	·033	·923	·110	+ 7·56
63·3875	4473·031	·003	·957	·046	+ 3·08	49·2552	4332·998	·983	988	·005	− 0·35
62·8042	4466 751	....	·727	...	....	S 48·4743	4325·939	.....	·939	.....	....
62·8162	4466·878	·858	·771	·087	+ 5·83	46·4606	4308·026	...	·081	..	....
61·0374	4448·007	·005	·892	·113	+ 7·60	40·6230	4258·386	·449	·477	·028	− 1·97

s_o = 218·9020
λ_o = 2792·051
log c = 5 4173335

ϵ = ± 4·26
ϵ_o = ± 1·18

Mean ..... + 3·39
V_a .... − 4·26
V_d ..... + 0·04
Curvature. − 0·50 − 4·72

Radial Velocity... .. − 1·3

* Cannot be used on account of unknown companion in star. Same in all the plates of this star.

β OPHIUCHI 327

1906. July 4. Observed by J. S. PLASKETT.
G. M. T. $16^h\ 30^m$ Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
70·1041	4549·640	...	·642	...	....	61·6412	4454·858	·898	·962	·064	−4·98
70·1108	4549·719	·719	·766	·047	−3·09	61·0093	4427·448	·470	·420	·050	+4·06
68·9338	4535·889	·899	·965	·066	−4·36	S 56·7792	4404·927	......	·927	.....	....
68·5246	4531·129	·139	·202	·063	·4·17	55·8036	4395·269	·259	·286	·037	−2·52
S 68·3220	4528·798	...	·798	...	....	54·6158	4383·668	.....	·720	.....	....
68·3200	4528·763	·773	·807	·034	−2·25	53·3300	4371·300	·280	312	·032	−2·19
67·8007	4522·780	·795	·855	·060	−3·97	52·9850	4368·014	·034	·071	·037	−2·53
65·3145	4494·702	...	·738	.....	....	51·3801	4352·908	·888	·923	·035	−2·40
64·2055	4482·471	·494	·434	·060	+4·01	51·2792	4351·968	·948	·006	·058	−3·99
63·6299	4476·193	......	·185	.....	....	S 48·4354	4325·939	......	·939	......	....
63·6257	4476·146	·168	·214	·046	−3·07	47·2285	4315·156	·156	·178	·022	−1·52
63·0152	4469·539	·559	·520	·039	+2·61	46·4276	4308·084	.....	·081	......	....
62·7528	4466·677	......	·727	..	....	44·8394	4294·255	·273	·273	....	0·00
62·0594	4459·300	·322	·304	·018	+1·20						

s_o = 217·2709
λ = 2806·634
log c = 5·4091088

ϵ = ± 2·83
ϵ_o = ± 0·66

Mean.... ... — 1·62
V_a .... — 8·12
V_d .... — 0·04
Curvature... — 0·50 — 8·66

Radial Velocity.... ..... — 10·3

β OPHIUCHI 334.

1906. July 6.
G. M. T. 16h 25m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
70·1490	4549·692	...	·642	..	....	62·6100	4464·837	·822	·772	·050	+3·35
70·1518	4549·725	·700	·766	·066	−4·34	59·0296	4427·366	·340	·420	·080	−5·01
68·9727	4535·884	·889	·965	·077	−5·08	S 56·8049	4404·927	...	·927	....	....
68·5610	4531·104	·119	·202	·083	−6·14	55·8257	4395·245	·250	·286	·036	−2·45
S 68·3616	4528·798	...	·798	......	....	54·6447	4383·723	....	·720	..	....
68·3531	4528·700	·715	·807	·092	−6·75	53·3517	4371·300	·332	·312	·020	+1·37
67·8422	4522·820	·840	·855	·015	−0·83	53·0022	4367·974	·014	·071	·057	−3·91
65·3498	4494·702	...	·738	...	....	51·3990	4352·902	·932	·923	·009	+0·62
64·2347	4482·419	·429	·434	·005	−0·27	51·2961	4351·945	·975	·006	·031	−2·13
63·6662	4476·225	......	·185	....	....	49·9589	4339·609	·624	·684	·060	−4·14
63·6604	4476·161	·161	·214	·053	−2·95	S 48·4516	4325·939	....	·939	....	....
63·3571	4472·876	·890	·957	·067	−3·72	47·2407	4315·132	·122	·178	·056	−3·88
62·7855	4466·717	....	·727	......	....	46·4440	4308·106	.....	·081	...	....

s_0 = 217·4535
λ_0 = 2806·875
log c = 5·4094677

$\epsilon = \pm 2·77$
$\epsilon_0 = \pm 0·67$

Mean....... − 2·72
V_a .... − 8·91
V_d .... − 0·09
Curvature. − 0·50 − 9·50

Radial Velocity ..... − 12·2

β OPHIUCHI 353.

1906. July 18.
G. M. T. 16h 40m

Observed by J. S. PLASKETT.
Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
70·3261	4549·694	.....	·642	.....	....	58·0144	4415·271	....	·293	.....	....
70·3387	4549·842	·792	·766	·026	+ 1·71	S 56·9812	4404·927	......	·927	...	....
69·1679	4536·099	·049	·965	·084	+ 5·55	56·0125	4395·349	·369	·286	·083	+ 5·66
68·7524	4531·279	·239	·202	·037	+ 2·44	55·6725	4392·014	034	·029	·005	+ 0·34
68·5437	4528·859	......	·798	......	....	54·8131	4383·647	....	·720	.....	....
68·5453	4528·878	·838	·807	·031	+ 2·05	54·0138	4375·944	·964	·107	·043	− 2·94
68·0292	4522·938	·903	·855	·048	+ 3·18	53·5277	4371·297	·317	·312	·005	+ 0·34
S 65·5297	4494·738	......	·738	.. ..	....	53·3781	4369·871	·891	·856	·035	+ 2·40
63·8407	4476·202	.....	·185	......	....	50·1407	4339·660	·684	·684	..	0·00
63·8437	4476·235	·245	·214	·031	+ 2·07	49·8638	4337·131	...	·216	.....	....
63·5450	4472·999	·009	·957	·052	+ 3·48	S 48·6279	4325·939	.....	·939	......	....
62·9593	4466·690	.....	·727	.....	....	47·4360	4315·302	·297	·178	·121	+ 8·40
61·8490	4455·919	·939	·962	·023	− 1·54	46·6185	4308·090	......	·081	......	....
59·2210	4427·522	540	·420	·120	+ 8·12						

s_0 = 217·6937
λ_0 = 2806·270
log c = 5·4098049

$\epsilon = \pm 3·15$
$\epsilon_0 = \pm 0·78$

Mean .....+ 2·58
V_a .... − 13·63
V_d .... − 0·14
Curvature. − 0·50 − 14·27

Radial Velocity..... − 11·7

α ARIETIS 331.

1906. July 4.
G. M. T. $20^h\ 15^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
70·1910	4549·695	.....	·642	......	....	57·8560	4414·751	·731	·293	·562	—38·83
68·9771	4535·418	·400	·965	·565	– 37·34	62·8471	4466·754	.....	·727	......	....
68·5655	4530·631	·625	·202	·577	38·19	S 56·8767	4404·927	....	·927	......	....
S 68·4073	4528·798	......	·798	...	....	55·8451	4394·707	·706	·286	·580	39·55
68·3531	4528·171	·171	·807	·636	42·10	54·7221	4383·729	.....	·720	....	....
65·4055	4494·738	....	·738	......	......	53·8606	4375·412	·417	·107	·690	47·25
63·7212	4476·210	......	·185	.....	....	53·3698	4370·710	·722	·312	·590	40·47
63 3659	4472·354	·330	·957	627	42·00	52·0487	4358·199	·215	·670	·455	31·94
63·0550	4468 994	·974	·663	·689	46·23	51·4294	4352·401	·418	·923	·505	34·79
62·1010	4458·768	·744	·304	·560	37 57	50·5322	4344·080	·097	·597	·500	– 34·50
61·6860	4454·359	·335	·962	·627	42·19	S 48·5423	4325·939	.....	·939	.....	....
59·0447	4426·838	·816	·420	·604	—40·89	46·5401	4308·114	.....	·081	......	....

$s_\circ = 217·1678$
$\lambda_\circ = 2806·818$
$\log c = 5·4085157$

$\epsilon = \pm 4·11$
$\epsilon_\circ = \pm 1·06$

Mean......		– 39·59
V_a	+ 26·35	
V_d	+ 0·23	
Curvature	– 0·50	+ 26·08
Radial Velocity....		– 13·5

α ARIETIS 337.

1906. July 6.
G. M. T. $20^h\ 15^m$

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
70·2077	4549·672	....	·642	...	....	59·0510	4426·799	·780	·420	·640	–43·32
68 9903	4535·328	·320	·965	·645	–42·63	57·8585	4414·694	·678	·293	·615	41·75
68·5825	4530·588	·588	·202	·614	40·64	57·5606	4411 697	·687	·200	·513	34·83
S 68·4279	4528·798	....	·798	.....	....	S 56·8833	4404·927	......	·927	......	....
68·3740	4528·176	·180	·807	·627	41·50	55·8409	4394·617	·642	·286	·644	43·92
67·8550	4512·198	·236	·943	·707	46 94	54·7208	4383·687	.....	·720	....	......
65·4206	4494·710	.....	·738	.....	....	53·8617	4375·406	·450	·107	·657	45 00
64·2381	4481·674	·710	·434	724	48·43	53·3715	4370·719	·760	·312	·552	38·55
63·7355	4476·195	...	·185	.....	......	52·1511	4359·174	·210	·670	·460	32·28
63·3819	4472·361	·371	·957	·586	39·26	51·4269	4352·347	·377	·923	·546	38·30
63 0624	4468·912	·922	·663	·741	49 72	51·3160	4351·372	·402	·006	·604	–41·61
62·8563	4466·695	.....	727	..	......	S 48·5341	4325·939	.....	·939	..	....
62 0966	4458·573	·573	·304	·731	48·97	46·5308	4308·141	....	·081	......	....
61 6873	4454·231	·226	·962	·736	—49·53						

$s_\circ = 216·6847$
$\lambda_\circ = 2814·151$
$\log c = 5·4051895$

$\epsilon = \pm 4·97$
$\epsilon_\circ = \pm 1·17$

Mean		– 42·51
V_a	+ 26·74	
V_d	+ 0·23	
Curvature.	– 0·50	+ 26·47
Radial Velocity		– 16·0

α ARIETIS 364.

1906. Aug. 1.
G. M. T. 19h 30m

Observed by W. E. Harper.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
72·9557	4583·810	...	·018	......	....	57·7290	4414·611	·653	·293	·640	−43·45
71·3877	4564·784	·974	·726	·752	−49·33	S 56·7613	4404·927	.....	·927	.....	....
70·2927	4551·734	·860	·594	·734	48·22	56·6863	4404·180	·191	·951	·760	51·75
70·1052	4549·518	.....	·642	....	....	55·7136	4394·569	526	·286	·760	51·75
70·0580	4548·961	·076	·766	·690	45·40	54·6112	4383·813	.....	·720	......	....
68·8780	4535·153	·205	·965	·760	50·23	54·0871	4378·750	·736	·396	·660	45·14
68·4705	4530·435	·452	·202	·750	49·57	53·2618	4370·841	·712	·312	·600	41·16
S 68·3286	4528·798	......	·798	.....	....	51·9311	4358·253	·123	·711	·588	40·39
68·2603	4528·011	·011	·807	·796	52·69	51·3056	4352·404	·273	·923	·650	44·78
67·7502	4522·156	·132	·855	·723	47·93	51·2027	4351·632	·502	·006	·504	34·72
65·3235	4494·833	......	·738	......	....	49·5970	4336·647	·536	·216	·680	46·98
64·1417	4481·836	·756	·434	·678	45·35	49·2478	4333·466	·346	·925	·579	40·00
63·6300	4476·270	...	·185	.....	....	48·4254	4326·024	....	·939	.....	....
63·5688	4475·606	·534	·214	·680	45·47	47·1544	4314·663	·593	·178	·585	40·65
63·2642	4472·312	·248	·957	·709	47·50	46·4206	4308·180	......	·081	.....	....
62·9495	4468·923	·907	·520	613	41·13	S 44·8286	4294·301	......	·301	......	....
62·7445	4466·722	.....	727	.....	....	44·7440	4293·571	·577	·273	·696	48·30
62·6855	4466·089	·097	·771	·674	45·22	44·0372	4287·495	·504	·134	·630	44·03
61·5669	4454·194	·284	·962	·678	45·62	42·4963	4274·418	·422	·922	·500	−35·05
58·9280	4426·774	·854	420	·566	−38·31	42·2165	4272·067	......	·934	.....	....
57·7916	4415·243	......	·293	......	....						

$s_0 = 219·8443$
$\lambda_0 = 2782·388$
$\log c = 5·4226038$

$\epsilon = \pm 4·68$
$\epsilon_0 = \pm 0·88$

	Mean......	− 45·00
V_a........ + 28·83		
V_d....... + 0·14		
Curvature.. − 0·50		+ 28·47
Radial Velocity...		− 16·5

α ARIETIS 393.

1906. Sept. 10
G. M. T. 19h 05m

Observed by W. E. Harper.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
S 68·3295	4528·798	...	·798	.....	....	57·8198	4415·189	.....	·293	.....	....
68·2791	4528·214	·217	·807	·590	−39·00	S 56·7961	4404·927	.....	·927	....	....
67·7681	4522·321	·365	·855	·490	33·15	55·7538	4394·611	·706	·286	·580	−40·23
64·1633	4481·877	·967	·434	·467	31·24	54·6241	4383·583	....	·720	.....	....
63·6339	4476·099	......	·185	.. .	... .	53·2800	4370·661	·782	·312	·530	−36·35
63·2871	4472·335	·427	·957	.530	−35·51	S 48·4498	4325·939	....	·939	... .	....
62·7623	4466·672	.....	·727	....	....	46·4466	4308·141	.....	·081	....	....

$s_0 = 215·7091$
$\lambda_0 = 2822·039$
$\log c = 5·4006095$

$\epsilon = \pm 3·40$
$\epsilon_0 = \pm 1·38$

	Mean........	− 35·91
V_a.. .... +21·58		
V_d.. .... + 0·09		
Curvature. − 0·50		+ 22·17
Radial Velocity		− 13·7

α PERSEI 330

1906. July 4.
G. M. T. 19ʰ 50ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
70·0696	4549·648	.....	·642	.....	....	62·4997	4464·397	·377	·617	·240	−16·10
70·0496	4549·411	·391	·642	·251	−16·51	62·0265	4459·342	.....	·301	.....	.....
68·7235	4533·858	·873	·139	·266	17·58	61·9936	4458·991	·956	·301	·315	23·18
S 68·2871	4528·798	.....	·798	.....	....	61·1749	4450·322	·280	·597	·317	21·33
67·7381	4522·477	·527	·802	·275	18·23	S 56·7439	4404·927	.....	·927	.....	....
67·6928	4515·104	·165	·508	·343	22·77	56·7195	4404·685	·670	·927	·257	17·47
66·4705	4508·055	·125	·455	·339	21·91	54·5877	4383·725	.	·720	.....	.....
65·8567	4501·158	·220	·448	·228	15·18	52·9040	4367·566	·606	·839	·233	15·98
65·2762	4494·685	.....	·738	.....	....	48·4091	4325·958	.....	·939	.....	.....
64·9580	4491·158	·213	·570	·337	22·47	46·4035	4308·102	.....	·081	.....	....
64·0369	4481·031	·061	·400	·339	22·67	46·3687	4307·794	·764	·081	·317	22·03
63·5946	4476·211	.....	·185	.....	....	S 40·8355	4260·640	.....	·640	.....	....
63·5636	4475·874	·875	·185	·310	−20·73	40·7961	4260·315	·315	·640	·325	22·84
62·7138	4466·693	.....	·727	.....	....	44·7842	4293·984	·944	·273	·329	−22·96

s_o = 218·1580
λ_o = 2796·637
log c = 5·4143058

$\epsilon = \pm 2{\cdot}95$
$\epsilon_o = \pm 0{\cdot}71$

Mean...... −19·99
V_a .... +16·85
V_d .... + ·21
Curvature.. − ·50 +16·56

Radial Velocity........ − 3·4

α PERSEI 336.

1906. July 6.
G. M. T. 19ʰ 35ᵐ

Observed by J. S. Plaskett.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal. W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal. W. L.	Displacement.	Velocity.
S 68·4356	4528·798	.....	·798	...	....	62·1424	4459·032	·017	·301	·284	−19·08
67·6846	4520·163	·163	·397	·244	−15·51	61·3255	4450·391	·366	·597	·231	15·54
67·2575	4515·292	·302	·508	·206	13·67	S 56·8823	4404·927	.....	·927	.....	.....
66·6295	4508·179	·195	·455	·260	17·32	56·8578	4404·683	·673	·927	·254	17·27
66·0096	4501·215	·235	·448	213	14·18	54·7200	4383·701	.....	·720	.....	....
65·4301	4494·757	.....	·738	.....	....	54·6860	4383·371	·396	·720	·324	22·12
64·1949	4481·155	·160	·400	·240	16·05	53·0391	4367·588	·618	·839	·221	15·16
63·7372	4476·171	.....	·185	.....	....	51·3430	4351·660	680	·006	·326	22·46
63·7144	4475·920	·920	·185	·265	17·72	S 48·5288	4325·939	.	·939	.....	....
62·8594	4466·695	.....	·727	...	....	48·4997	4325·677	·667	·939	·272	18·84
62·8331	4466·412	·402	·727	·325	21·80	47·0521	4312·784	·734	·034	·300	20·85
62·6435	4464·380	·375	·617	·242	−16·23	46·5265	4308·156	.....	.081	.....	....
62·1715	4459·342	.....	·301	.....	....	46·4943	4307·870	·815	·081	266	−18·51

s_o = 217·1005
λ_o = 2810·985
log c = 5·4071842

$\epsilon = \pm 2{\cdot}76$
$\epsilon_o = \pm 0{\cdot}67$

Mean..... −17·78
V_a ... + 17·46
V_d ...... + ·21
Curvature − ·50 +17·17

Radial Velocity .... − 0·6

α PERSEI 411.

1906. Oct. 16. G.M.T. 19h 45m

Observed by W. E. Harper.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L	Displacement.	Velocity.
72·8313	4584·007	....	018	. . .	....	55·7267	4395·032	·032	·286	·254	−17·32
71·8449	4571·903	·887	·156	·268	−17·42	55·6200	4393·978	·978	·225	·247	16·84
71·1720	4563·740	·708	·939	·231	15·15	54·8832	4386·741	·757	·007	·250	17·07
70·7378	4558·512	·472	·827	·355	23·32	54·5717	4383·701	.....	·720	.....	....
69·9990	4549.688	...	·642	...	......	54·5442	4383·433	·450	·720	·270	18·46
69·9795	4549·457	·417	·642	·225	14·82	53·7645	4375·876	·907	·107	200	13·70
67·6823	4522·581	·589	·802	·213	14·12	48·4183	4325·942	......	·939	...	....
S 68·2200	4528·798	....	·798	....	....	46·4143	4308·029	......	·081	......	....
65·7999	4501·166	·190	·448	·258	17·18	46·3927	4307·838	·838	·081	·243	16·88
65·2275	4494·758	..	·738	.....	....	45·1015	4296·519	·495	761	·266	18·56
65·2024	4494·478	·498	·738	·240	16·00	44·8499	4294·334	. .	·301	......	....
63·5425	4476·174	...	·185	......	....	43·4866	4282·600	. ..	·565	....	....
62·6766	4466·780	......	·727	.....	....	43·4607	4282·379	·355	·565	·210	14·70
62·4570	4464·416	·367	·617	·250	16·77	S 40·8765	4260·640	.....	·640	.....	....
61·9830	4459·332	.....	·301	......	....	40·8470	4260·396	370	·640	·270	18·98
61·1480	4450·453	·403	·654	·251	16·89	40·5680	4258·087	062	·391	·329	23·16
57·9001	4416·798	·758	·985	·227	15·39	40·1031	4254·257	·255	·505	·250	17·62
57·7472	4415·248	. . .	·293	. ...	....	39·1867	4246·766	·774	·996	222	15·67
S 56·722)	4404·927	. . .	·927	.....	....	37·8667	4236·109	..	·112	......	....
56·6990	4404·696	·687	·927	·240	−16·32	37·8276	4235·795	·815	·112	·297	−20·99

s_o = 217·5462
λ_o = 2796·198
log c = 5·4128342

ϵ = ± 2·14
ϵ_o = ± 0·43

V_a .... + 15·48
V_d . . .. − ·05
Curvature. − ·50

Mean........ − 17 22
+ 14·93

Radial Velocity........ − 2·3

ε PEGASI 378.

1906. Aug. 15 G. M. T. 16h 45m

Observed by W. E. Harper.
Measured by W. E. Harper.

Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W, L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W. L.	Normal W. L.	Displacement.	Velocity.
68·4915	4531·303	·293	·202	·091	+6·01	62·7000	4466·725	......	·727	......	....
S 68·2750	4528·798	.....	·798	.....	....	62·7122	4466·855	·835	·771	·064	+4·29
(8·2675	4528·711	·717	·807	·090	−5·95	58·9544	4427·474	·431	·420	·014	+0·94
67·7616	4522·888	·918	·855	·063	+4·17	S 56·7194	4404·927	. ..	·927	......	....
65·2585	4494·646	....	·738	......	... .	55·6224	4394·088	·148	·161	·013	−0·88
64·8316	4489·922	·982	·911	·071	+4·74	54·5440	4383·575	......	·720	...	....
64·1561	4482·501	·531	·434	·097	+6·48	53·2654	4371·289	·369	·312	·057	+3·91
63·5775	4476·196	.. .	·185	.. .	....	S 48·3664	4325·939	.. ..	·939	.....	....
63·5801	4476·225	·235	·214	·021	+1·40	46·3560	4308·081	......	·081	. ..	....
62·9645	4469·568	·558	·520	038	+2·54						

s_o = 217·2923
λ_o = 2807·524
log c = 5·4090867

ϵ = ± 3·57
ϵ_o = ± 1·07

V_a .... +3·61
V_d .... ·00
Curvature . − ·50

Mean........ + 2·51
+ 3·11

Radial Velocity.... ... + 5·6

ϵ PEGASI 400

1906. Sept. 27.
G. M. T. $15^h 40^m$

Observed by W. E. HARPER.
Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
68·2774	4528·888	.....	·798	...	....	54·5823	4383·690	......	·720	......	....
S 65·2667	4494·738	....	·738	....	....	54·1811	4379·802	·832	·396	·436	+29·82
63·9630	4480·364	·384	·249	·135	+ 9·03	53·3357	4371·671	·702	·312	·390	26·71
63·5792	4476·178	......	·185	.. ..	....	53·1862	4370·243	·276	·856	·420	28·77
63·3167	4473·328	·337	·957	·380	25·46	51·3943	4353·312	·343	·923	·420	28·89
62·7011	4466·680	......	·727	......	....	49·2135	4333·192	·212	·988	·224	15·50
61·6398	4455·343	·352	·962	·390	26·24	S 48·4133	4325·939	......	·939	......	....
60·0381	4438·520	·500	·344	·156	10·53	47·9028	4321·348	·343	·992	·351	+24·32
59·0027	4427·825	·795	·420	·375	+25·38	46·4139	4308·112	......	·081	.....	....
S 56·7395	4404·927	.....	·927	.. ...	....						

s_o = 218·1741
λ_o = 2794·460
log c = 5·4149485

$\epsilon = \pm 8·11$
$\epsilon_o = \pm 2·44$

	Mean......	+22·79
V_a........	−15·63	
V_d........	− ·12	
Curvature..	− ·50	−16·25
Radial Velocity........		+ 6·5

ϵ PEGASI 409.

1906. Oct. 16.
G. M. T. $15^h 47^m$

Observed by W. E. HARPER.
Measured by W. E. HARPER.

Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.	Mean of Settings.	Computed Wave Length.	Corrected W.L.	Normal W.L.	Displacement.	Velocity.
73·0683	4586·705	·690	·163	·527	+ 34·36	62·6853	4466·709	..	·727	......	....
72·8520	4584·033	....	·018	......	....	62·7250	4467·137	·137	·771	·366	+24·55
72·5810	4580·689	·681	·228	·453	29·58	59·0001	4427·899	·929	·420	·509	34·45
70·2912	4552·953	·959	·594	·365	24·01	57·7571	4415·212	......	·293	....	....
S 70·0131	4549·642	......	·642	......	....	S 56·7350	4404·927	.....	927	......	....
70·0545	4550·135	·142	·766	·376	24·74	54·5821	4383·685	.....	·720	......	.. . ..
68·8933	4536·438	·438	·965	·473	31·26	53·3457	4371·738	·718	·312	·406	28·00
68·2378	4528·803	...	·798	......	....	52·2587	4361·383	·363	·958	·405	27·82
67·7612	4523·293	·285	·855	·430	28·50	48·4266	4325·936	..	·939	.. ...	....
65·2451	4494·773	.....	·738	......	....	47·6830	4319·243	·243	·817	·426	+ 29·56
63·5640	4476·239	......	·185	.....	....	46·4283	4308·081	......	·081	......	....
63·2975	4473·336	·312	·957	·355	+ 23·78						

s_o = 217·5228
λ_o = 2797·253
log c = 5·4124512

$\epsilon = \pm 3·73$
$\epsilon_o = \pm 1·07$

	Mean.....	+ 28·38
V_a......	− 22·18	
V_d......	− 0·22	
Curvature	− 0·50	− 22·90
Radial Velocity.. .		+ 5·5

SUMMARY OF RESULTS.

Dominion Observatory.				Other Observers.			
Star.	Plate.	Date.	Velocity Kms.	Observer.	Velocity Kms.	No. of Plates.	Range.
		1905.					
β Geminorum	196	Feb. 22, 15·5h	+ 4·2	Frost	+ 3·2	3	0·6
	197	" 22, 16·3h	+ 4·4	Adams	+ 3·7		0·2
	212	Mar. 5, 15·9h	+ 3·8	Lord & Maag	+ 5·3	5	5·4
		Mean	+ 4·1	Belopolsky	+ 3·4	9	1·4
		Range	0·6	Newall	+ 2·0	6	3·0
				Slipher	+ 3·3	3	0·2
α Boötis	199	Feb. 22, 18·6h	− 4·2	Frost	− 4·7	5	1·3
	216	Mar. 5, 19·7h	− 5·6	Adams	− 4·9		0·9
	220	" 23, 19·3h	− 4·6	Belopolsky	− 6·1	9	3·3
	230	" 28, 19·2h	− 4·7	Lord & Maag	− 3·2	7	3·2
	238	April 2, 19·9h	− 5·2	Frost, Adams	− 4·3	8	1·8
	252	" 24, 15·9h	− 5·5	Newall	− 5·8	5	2·7
	253	" 24, 17·5h	− 3·4	Newall	− 6·6	19	4·5
	300	June 18, 14·4h	− 4·7	Slipher	− 4·7	5	1·4
	312	" 27, 13·9h	− 4·9				
	319	July 2, 14·3h	− 5·1				
	325	" 4, 13·9h	− 3·3				
		Mean	− 4·6				
		Range	2·3				
γ Aquilae	323	July 2, 19·2h	− 2.0	Frost	− 1·4	3	0·7
	323	" 2, 19·2h	− 1·6	Adams	− 2·2		1·0
	329	" 4, 19·0h	− 1·3	Belopolsky	− 2·0	10	3·8
	335	" 6, 18·4h	− 1·8	Newall	− 1·9	4	4·2
	354	" 18, 18·1h	− 2·1	Slipher	− 2·1	3	1·4
	361	Aug. 1, 16·5h	− 1·3				
		Mean	− 1·7				
		Range	0·8				
		1906.					
β Ophiuchi	327	July 4, 16·5h	−10·3	Frost	−11·3	3	0·8
	334	" 6, 16·4h	−12·2	Adams	−10·9		0·7
	353	" 18, 16·7h	−11·7	Newall	−15·8	2	1·9
				Slipher	−11·3	3	1·1
		Mean	−11·4				
		Range	1·9				
α Arietis	331	July 4, 20·2h	−13·5	Frost	−13·5	3	0·8
	337	" 6, 20·2h	−16·0	Adams	−13·8	4	0·7
	364	Aug. 1, 19·5h	−16·5	Campbell	−14·1	4	0·6
	393	Sept. 10, 19·1h	−13·7	Newall	−14·3	3	2·8
				Lord & Maag	−12·4	5	1·8
		Mean	−14·9	Newall	−16·4	8	6·3
		Range	3·0	Slipher	−14·3	3	0·5
α Persei	330	July 4, 19·8h	− 3·4	Frost	− 2·3	3	1·6
	336	" 6, 19·6h	− 0·6	Adams	− 2·0		1·3
	411	Oct. 16, 19·7h	− 2·3	Campbell	− 2·2	10	2·0
				Belopolsky	− 2·9	8	3·7
		Mean	− 2·1	Lord & Maag	+ 0·6	5	3·7
		Range	2·8	Newall	− 2·6	14	5·7
				Vogel	− 3·2	13	3·3
				Newall	− 2·6	5	5·5
				Slipher	− 2·5	5	1·3
ε Pegasi	378	Aug. 15, 16·7h	+ 5·6	Frost	+ 6·2	3	0·5
	400	Sept. 27, 15·7h	+ 6·5	Adams	+ 6·2		0·4
	409	Oct. 16, 15·8h	+ 5·5	Campbell	+ 5·7	4	1·2
				Belopolsky	+ 6·0	7	1·4
		Mean	+ 5·9	Lord & Maag	+ 6·1	5	5·8
		Range	1·0	Newall	+ 3·3	3	2·6
				Slipher	+ 6·1	4	1·8

CONCLUSION.

For convenience of reference the radial velocities determined are tabulated above, along with those obtained by other observers of the same stars, with the range, or difference between the greatest and least values of the radial velocity.

It must be remembered in comparing the Ottawa results with those of other observers, that the dispersion of the instrument used here is about 40 per cent less, thus increasing the relative error of setting on the lines; that our results were obtained from an adapted universal spectroscope which no one else has been able to use for the purpose, their spectrographs, with one exception, being specially designed and constructed for radial velocity work; and finally that all the velocities given here were obtained within a few months of starting work on the spectrograph, the instrument during that period having been put into condition to do accurate work, while so far as I know no other observations were published within two years.

In conclusion, I wish to express my deep appreciation of the readiness with which you acted on any suggestions of mine looking towards the improvement of the present instrument and the construction of a new one, and of the kindly encouragement and help you have always afforded me.

I have the honour to be, sir,
Your obedient servant,

J. S. PLASKETT.

APPENDIX 3

REPORT OF THE CHIEF ASTRONOMER.

TIME SERVICE SYSTEM

BY

R. M. STEWART, M.A.

CONTENTS.

ILLUSTRATIONS.

APPENDIX 3.

REPORT OF R. M. STEWART, M.A., ON THE TIME SERVICE.

OTTAWA, ONT., July 31, 1906.

W. F. KING, Esq., B.A., LL.D., &c.,
Chief Astronomer,
Ottawa.

SIR,—I have the honour to present the following report of the operations in connection with the Time Service of the observatory since my last report.

During the past nine months time determinations have been taken on about 75 different nights. On a large proportion of these occasions one, and in very many cases two, complete sets of 12 stars have been observed; on the remainder the sets consisted usually of 6 or 8 stars. In addition to the ordinary distribution of time, these observations have served for determinations of the longitudes of a number of stations, and also furnish considerable data for the accurate rating of the sidereal clocks.

The Riefler sidereal standard has been in use continuously during this time, except for a week at the beginning of February and about three weeks towards the end of June, when the time was taken from the Howard, which is always compared with it daily. A continuous record of the temperature of the clock room has been kept, and also of the atmospheric pressure, while during the greater part of the time the temperature and pressure inside the sealed case of the Riefler clock have been read daily. The time service to the departmental buildings and the observatory has been continued, and is giving satisfaction. Since December 1, 1904, the time-ball on Parliament Hill, which gives the signal for the firing of the noon-day gun, has been dropped by the master-clock at the observatory, and since January 2, 1905, the time has been furnished daily (holidays excepted) to the Great North Western Telegraph Company. The Canadian Pacific Telegraph Company also made a request to have the time furnished them occasionally, at their head offices in Montreal, but owing to pressure of business on their lines, have been able to avail themselves of it only a few times.

CLOCK ROOM.

The constancy of temperature in the clock room has not been as satisfactory as could be desired. As stated in the last report, the apparatus for temperature control consists of an electric heater which is automatically turned on and off by a thermostat, while an electric fan keeps the air in constant circulation. The thermostat in use at that date was simply a special form of minimum thermometer with an electrical contact. It consisted of a U-shaped tube with a bulb at one end containing a liquid whose expansion measured the temperature. Below this liquid, and filling the bent portion of the tube, was a column of mercury which made connection with a binding post by means of a wire sealed through the glass. A movable iron dumb-bell in the tube, connected with another binding post, served to establish a circuit when the temperature dropped to such a point that the mercury touched it. The apparatus was not particularly sensitive, allowing an oscillation of fully a degree Fahrenheit between maximum and minimum; still, as this oscillation took place every few minutes, it was not particularly objectionable. But the fatal objection was that, through the repeated pressure of the mercury against the dumb-bell at each successive contact, the latter was gradually but surely pushed along the tube, causing a con-

tinual creeping of the zero, and a consequent gradual falling of the temperature in the room. After some experiment it was abandoned, and a new thermostat made, which it was hoped would prove more satisfactory, and which is still in use. It consists of a strip of hard rubber and one of brass fastened firmly together by screws along their whole length; one end of the combination is rigidly attached to a base-plate, while the other end is fitted with a platinum contact abutting against an insulated contact screw attached to the base-plate. Owing to the difference in the thermal expansions of the components, the bar bends in one direction or the other as the temperature rises or falls, and the contact operates the relay controlling the heating circuit. Hard rubber was chosen as one of the components on account of its large coefficient of expansion; the same sensitiveness as obtained from this thermostat with a length of thirteen inches would, with zinc and iron, the next most advantageous combination, require a length about three times as great, a fact which assumes considerable importance because the stability of the instrument and the firmness of the contact decrease with the length. The performance of the new thermostat is at least a considerable improvement on that of the old one, but it is not all that could be desired. The sensitiveness is much greater, the extreme range of temperature being not more than one, or at most two, tenths of a degree Fahrenheit. For a considerable time, too, no shifting of the zero became apparent, but later some irregularities showed themselves, culminating finally in a gradual decrease in the temperature from 71° F. on March 20, to 65½° F. about May 20, during which time the adjustment was not altered; since that time, however, it has remained nearly constant. The explanation seems to lie in the hygrometric state of the air; when the air is moist the hard rubber absorbs moisture and expands, and vice versa; the shifting of the zero follows as an obvious consequence. The beginning of the period, March 20 to May 20, corresponds to the diminution of artificial heat in the building and the consequent increase of moisture in the basement, where the clock room is situated. Such a constant and gradual change in temperature is of course not so objectionable as more rapid and irregular fluctuations; the effect is simply a slow change in clock rates; it is, however, not by any means desirable. When the Callendar apparatus recently ordered arrives, all difficulty on that score will no doubt be removed. This Callendar apparatus consists essentially of a Wheatstone bridge in which the slider is automatically moved along the bridge wire until the resistance of a platinum thermometer is balanced. An electric contact operated by the slider will control the heating circuit, and a pen which it carries will at the same time furnish a record of the temperature. Besides being extremely sensitive, the temperature control depends directly on a platinum thermometer, which is considered to be even less liable to variation than a mercury one. Another source of trouble arose from the presence in the clock room of two ventilators opening into the two main ventilating shafts of the building. During the winter, whenever a strong wind was blowing, enough draught was forced in even through the closed ventilators to cause a very material difference in temperature between the two ends of the room. On the discovery of this fact, the ventilators were removed and the openings sealed up, with the exception of a small window which could be opened or closed by a sliding shutter.

RIEFLER CLOCK.

A considerable amount of trouble was experienced with the maintaining of the partial vacuum in the Riefler clock. Naturally it was at first thought to be due to defective sealing of the cylinder when the clock was exhausted; consequently about the beginning of February the cylinder was opened and very carefully resealed. On account of the slowness of the leak (about 2 mm. per month), and also on account of the slight variations of temperature in the clock room, it required considerable time to come to a definite conclusion, but by about the beginning of April the persistence of the leak became evident, and it was finally located in the bushing which contained the leads for the electric circuits. On tightening this bushing the pressure remained practically constant for a month and a half, when the leak became more pronounced

than ever, and it was finally determined to take the clock out of commission and make a thorough examination. The bushing consisted of a cylinder of hard rubber with a flange at one end and a thread at the other; the lower side of the flange abutted against the plate of thick glass which formed the bottom of the clock cylinder, and was held tightly in place by the nut which screwed on the other end of the bushing outside the clock. Through the bushing ran the four leads for the winding circuit and the seconds-contact circuit. It was found that the hard rubber had not been sufficiently rigid to withstand the strain due to the necessary tightness of the nut, and had cracked just around the inner edge of the flange. In making a new bushing, it was decided to use a brass shell to withstand the strain, and through it to run a hard rubber cylinder. A section of the new bushing is shown in fig 1; *a* is the plate glass bottom of the clock cylinder, *b* the brass shell with a flange at the upper end, and *c* the hard rubber through which the leads (not shown) are run; the nut *d* clamps the brass shell to the clock-base, and the shoulder of the nut *e*, pressing against the flange near the lower end of *c*, holds it firmly in place. The leads consist of small brass rods with a shoulder at one end and a nut at the other by which they were tightened firmly. To make the joints more surely air-tight they were lined throughout with a liquid cement before assembling the parts. The bushing was put in place on June 26, and the clock exhausted on June 29. Since that time there has been no measurable leak.

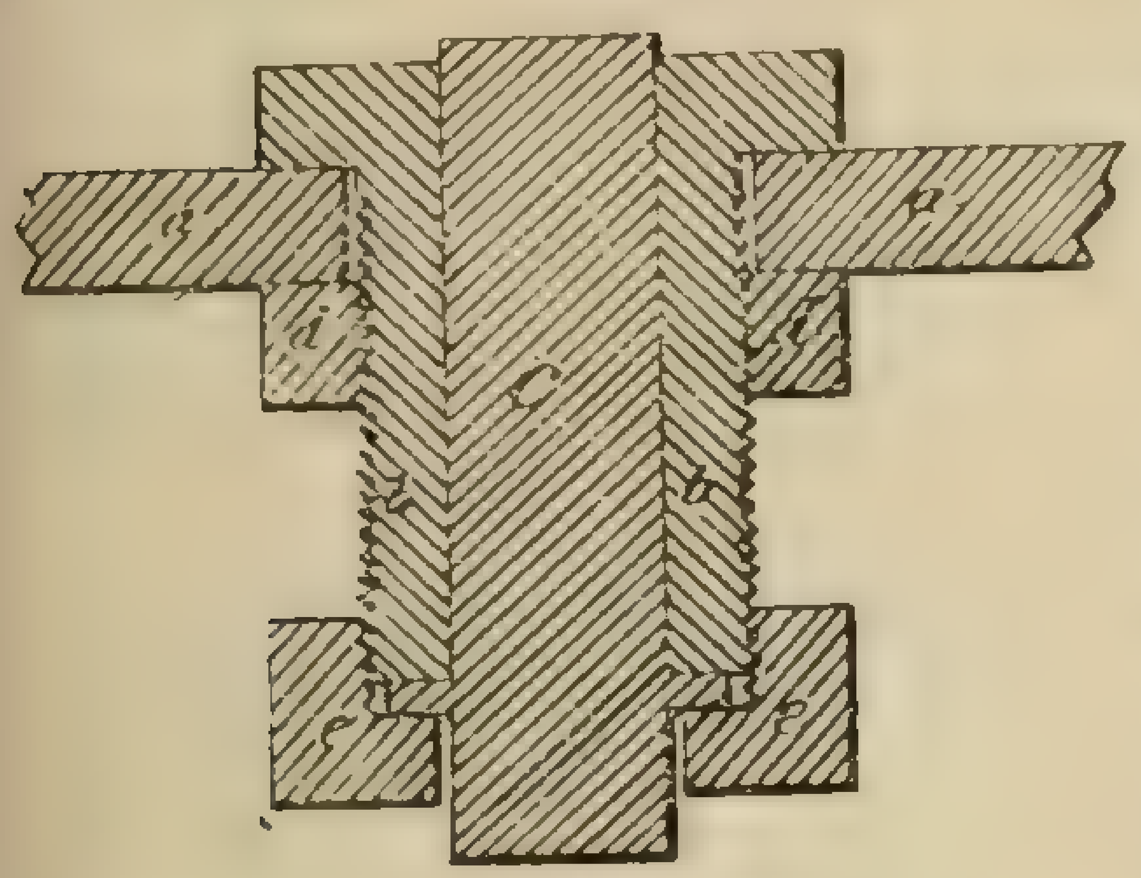


Fig. 1.—Air-tight bushing in Riefler clock.

A considerable quantity of data has accumulated for the rating of the Riefler, but the necessary computations for a thorough analysis of its constancy of rate and of the variations due to temperature and pressure have not been made. It may be of interest, however, as giving a rough idea of its accuracy, to show in tabular form a record of its performance for a few months. The period chosen (February 5 to May 14) has been taken at random, and is the only one for which even such a rough analysis has been made. It seems best to divide this period into two parts; during the first part the clock was leaking slightly, and the temperature in the clock room was fairly uniform; during the second there was no appreciable leak, but the temperature was slowly decreasing; so that we should expect to find a difference in the average rate during the two periods. The column headed Δ T in Table I. shows the clock-correction as determined by observation on the dates mentioned; the next column shows the observed gain or loss in seconds for each interval, a positive sign denoting a loss, and vice versa; in the fourth column is given the average daily rate for each of the two periods, and in the fifth the loss or gain which would have taken place during each interval at this average rate. The last column gives the difference between the observed and computed variations. For a rough test of how far these differences may be due to errors of observation, we may resort to an indirect method. In an extended series of observations for personal equation by two observers, the probable error (*of a single determination*) derived by a comparison of the different values obtained is evidently closely analogous to the probable error of the *difference* of two time determinations made by the same observer. In a series of personal equation observations consisting of eight different determinations, made by the writer with Mr. McDiarmid in the spring of 1905, the probable error of a single determination was about ·053 second; and in a similar series of ten determinations in the spring of 1906, which have been only partially reduced as yet, it would appear to be about ·063 second. On comparing these results with column VI., it becomes at once apparent how remarkably true was the running of the clock; if we treat the differences in column VI. as residuals, and reduce in the usual way, we obtain a probable error of ·051 second, a value practically identical with those obtained from personal equation. The distribution of the differences as regards absolute magnitude also corresponds closely to that of the

TABLE I.

Date.	$\triangle$T	Observed loss or gain.	Average daily rate.	Loss or gain at average rate.	Diff.
Feb. 5	—7·05 sec.	—·07 sec.		·03 sec.	—·10 sec.
〃 8	—7·12 〃	·08 〃		·05 〃	·03 〃
〃 13	—7·04 〃	—·06 〃		·08 〃	—·14 〃
〃 21	—7·10 〃	—·01 〃		·01 〃	—·02 〃
〃 22	—7·11 〃	·04 〃		·05 〃	—·01 〃
〃 27	—7·07 〃	·07 〃		·06 〃	·01 〃
Mar. 5	—7·00 〃	·06 〃	+·010 sec.	·07 〃	—·01 〃
〃 12	—6·94 〃	·12 〃		·05 〃	·07 〃
〃 17	—6·82 〃	·21 〃		·12 〃	·09 〃
〃 29	—6·61 〃	·12 〃		·02 〃	·10 〃
〃 31	—6·49 〃	—·08 〃		.02 〃	—·10 〃
Apr. 2	—6·57 〃	·07 〃		·01 〃	·06 〃
〃 3	—6·50 〃				
〃 3	—6·50 〃	—·05 〃		—·01 〃	—·04 〃
〃 4	—6·55 〃	·05 〃		—·02 〃	·07 〃
〃 6	—6·50 〃	—·03 〃		—·10 〃	·07 〃
〃 16	—6·53 〃	—·10 〃		—·07 〃	—·03 〃
〃 23	—6·63 〃	—·01 〃		—·01 〃	·00 〃
〃 24	—6·64 〃	·01 〃	—·010 sec.	—·01 〃	02 〃
〃 25	—6·63 〃	·06 〃		—·03 〃	·09 〃
〃 28	—6·57 〃	—·13 〃		—·05 〃	—·08 〃
May 3	—6·70 〃	—·03 〃		—·03 〃	·00 〃
〃 6	—6·73 〃	—·24 〃		—·07 〃	—·17 〃
〃 13	—6·97 〃	·02 〃		—·01 〃	·03 〃
〃 14	—6·95 〃				

residuals in the personal equation computation. Of the 18 residuals, 8 are less than one-half of the probable error, 5 greater than twice, and 2 greater than three times the same quantity, while the corresponding numbers in the case of the 23 differences in Table I. are 7, 5 and 1, respectively. That is to say, these differences are closely analogous in their distribution and magnitude to the residuals to be expected if the clock-rate had been absolutely constant during each of the two periods. It would appear, then, so far as the above rough analysis is concerned, that there is no evidence whatever of any irregular variations in the rate of the clock. When all the data have been rigidly compared and computed, irregularities will no doubt show themselves, but it is probably safe to say that they will be quite small.

The primary recording and synchronizing circuit controlled by the Riefler is an intermittent one—that is, the circuit remains closed continuously for one second, and open for the following one, and so on alternately. This circuit is unsuited for use in recording observations on an ordinary chronograph; consequently observations were formerly taken with the Howard clock, which was compared with the Riefler on a special chronograph both before and after the observations. A device has, however, been adopted by which the circuit of the Riefler is transformed into the ordinary

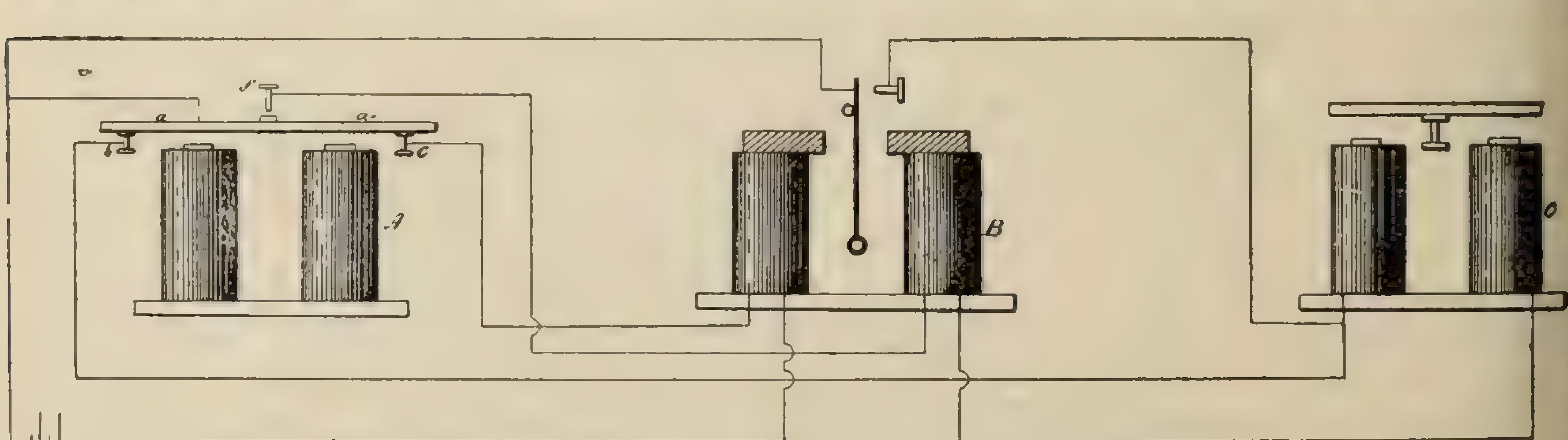


Fig. 2.—Transformation from intermittent to break circuit.

break-circuit type, suitable for use with an ordinary chronograph. The relay A (fig. 2) is the one controlled by the intermittent circuit; B is a differentially wound, neutrally adjusted polar relay, and C the relay which operates the transformed circuit. When the armature *a* of the relay A is held against the back contacts *b* and *c*, as shown in the figure, the circuit from the battery E holds the relay C closed, while it also so operates the relay B that the circuit through its points is open. When, on the opening of the primary circuit, the armature *a* leaves *b*, the circuit through C is opened; as soon, however, as *a* touches the front contact *f*, a circuit through B is completed which draws its armature to the right, again closing the circuit through C, which has thus been open only momentarily. When, a second later, *a* is again drawn down by the magnets, the armature of B returns to the left, *after* the circuit of C has been closed through *ab*. Consequently, the action of C consists of a short, sharp break every alternate second, as with the ordinary break-circuit contact. This device has been in use since about the beginning of April, and has given perfect satisfaction, giving a neater and more uniform break even than the Howard. This transformed circuit is used only for recording, the primary intermittent circuit, as before, performing the synchronizing functions of the clock. The synchronization has now been extended to the driving clock of the equatorial, giving a much more uniform rate to the latter. The apparatus for the purpose was made and installed by Mr. Plaskett.

HOWARD CLOCK.

A comparison by chronograph is made every morning between the Riefler standard and the Howard sidereal clock, and in this way considerable data have been accumulated for a determination of the variations in rate of the latter with temperature and atmospheric pressure. The mean temperature for any period may be found from the record of the thermograph in the clock room, while the pressure is taken from the recording aneroid barometer in the time room, which is compared daily with the standard mercury barometer to allow for the well known vagaries to which all aneroids are subject. As in the case of the Riefler, no detailed computation has been made as yet, but as an illustration some selected data of the means for various weeks are given in Table II. The periods were chosen so as to show as wide a range as possible, both in pressure and temperature; the second column gives the mean daily rate for each

TABLE II.

Interval.	Daily Rate.	Barometer.	Temperature.
November 13–20	—·061 sec.	752·6 mm.	74·5° F.
February 5–12	+·068 "	767·6 "	71·0 "
February 12–19	+·001 "	761·0 "	71·0 "
March 5–12	—·057 "	753·4 "	71·0 "
April 30—May 7	—·184 "	748·9 "	67·0 "
June 12–19	—·211 "	755·3 "	67·6 "
June 19–25	—·243 "	751·6 "	67·8 "
July 3–9	—·105 "	758·4 "	68·2 "

period in seconds, while the third and fourth contain the means of the pressure and temperature. While complicated somewhat by irregular variations, the indication is that roughly the clock loses ·01 sec. per day for an increase of 1 mm. in barometer, and ·02 sec. per day for an increase in temperature of 1° F.

TIME DISTRIBUTION.

As mentioned above, Standard time has been supplied daily since the beginning of 1906 to the Great North Western Telegraph Company, and on a few occasions to the Canadian Pacific Telegraph Company. The time signal relay beats seconds, omit-

ting the 29th second, and the last five seconds, of every minute; at the end of every fifth minute the last ten seconds are omitted, and at every even hour there is a single beat lasting one second, after which the line remains open for five or ten seconds. This circuit is switched on the telegraph line from 11.55 a.m. till 12.00 noon, and is distributed by the Telegraph Co. over the various lines. At present the circuit is switched on by hand, but when the programme clock which has been ordered arrives, the whole operation will be performed automatically by the clock. The operation of this time signal circuit necessitated the making and installation of several new contacts and an additional gear-wheel in the secondary master clock in the time room, which controls the circuit. These consist of a seconds contact, a minute contact, and a five minute contact. The seconds contact is controlled by a wheel with 54 teeth and 6 blank spaces, fixed on the arbor of the escapement wheel; each tooth, as it passes, presses aside a spring and opens the circuit for an instant; the blank spaces correspond to the 29th, 55th, 56th,........59th seconds. The five minute contact is controlled by the extra wheel, turning once in five minutes, and serves to short-circuit the seconds contact for the last ten seconds of every fifth minute. The minute contact is controlled by a hard rubber cam on the axis of the escapement wheel, and closes its circuit for the first second of every minute. It is operated in series with the hourly contact, thus giving a signal of one second duration exactly at the even hour. The writer is indebted to Mr. Plaskett for considerable assistance in making these contacts. Some slight further modifications may be found necessary, as, owing apparently to a lack of trueness in the escapement wheel, the beats during one part of the minute are not perfectly uniform. The mean time primary clock is compared daily with the sidereal standard shortly before noon, and any necessary correction made; at the time of sending the signals, its error is practically never more than one-tenth, or at most, two-tenths of a second; on one occasion, owing to a mistake in computation, it was one second in error; on two or three occasions trouble on the telegraph line prevented signals being sent at all.

The Canadian Pacific time signals are sent out from the head offices of the company in Montreal. A short line runs from there to McGill College observatory, over which the beats of the McGill clock are transmitted continuously. In accordance with these the time signals are sent out over the various lines by hand. The company made a request for occasional time signals from the Dominion observatory for purposes of comparison, and these have been given whenever called for. On account of pressure of business on their lines between Ottawa and Montreal the connection has been made only a few times. On several of these occasions the beats of the McGill clock were also received at the observatory, and on one occasion the time signals of the company. The different dates and the amount of disagreement with the observatory time on each date are as follows:—

July 3, C.P.R. time signals..................	$\frac{1}{4}$ sec. fast.
" 4, McGill clock......................	$\frac{3}{4}$ "
" 5, "	No difference.
" 11, "	$\frac{1}{4}$ sec. fast.
" 12, "	$\frac{1}{2}$ "
" 13, "	$\frac{3}{4}$ "

A glance at Table I. will show that these discrepancies were certainly not due to variations in the observatory clock.

Through the courtesy of the Great North Western Company, the beats of the Washington signal clock were received at midnight of December 31, 1905, and at 1 a.m. January 1, 1906. The agreement between these and the observatory time was very close, there being a difference of certainly not more than a tenth of a second.

On December 1, 1905, connection was made with the time-ball on Parliament Hill, which has been dropped from the observatory since that date. The circuit which controls the ball is the hourly signal circuit described above, and is automatic in operation. On two occasions a failure of the line has prevented the working of the signal, while

once the same result was caused by a burnt-out fuse. For upwards of a week, while the new contacts were being installed in the clock, the noon signals, as also the telegraphic time signals, were controlled by hand.

A circuit has been arranged for recording the time on the observatory seismograph. It is worked by one of the contacts on the master-clock, and controls a shutter on the seismograph which, when the circuit is closed, shuts off the beam of light which makes the record on the revolving cylinder. It operates once a minute, for a period of two seconds; the signal corresponding to the even hour is omitted for convenience in reading the time from the record.

Several seconds-dials have been ordered for use in those rooms where time in seconds is required. These will be operated by the two secondary master-clocks in the time room—some by the mean time, some by the sidereal. Before those to be operated by the sidereal clock can be connected, it will be necessary to install a new contact in the latter, as the one now in place has a tendency to 'miss fire.'

The dials in the parliament and departmental buildings are now working in a thoroughly efficient manner. During the winter of 1905-1906 especially, and also previously, a certain amount of trouble occurred in the parliament building and the east block, and to a less extent in the west block. These three buildings were equipped with Riefler secondary master-clocks, in which the contact controlling the dial circuits was somewhat uncertain. It was decided to replace these contacts by new ones of a different type; this has already been done in the case of the east block and the parlia-

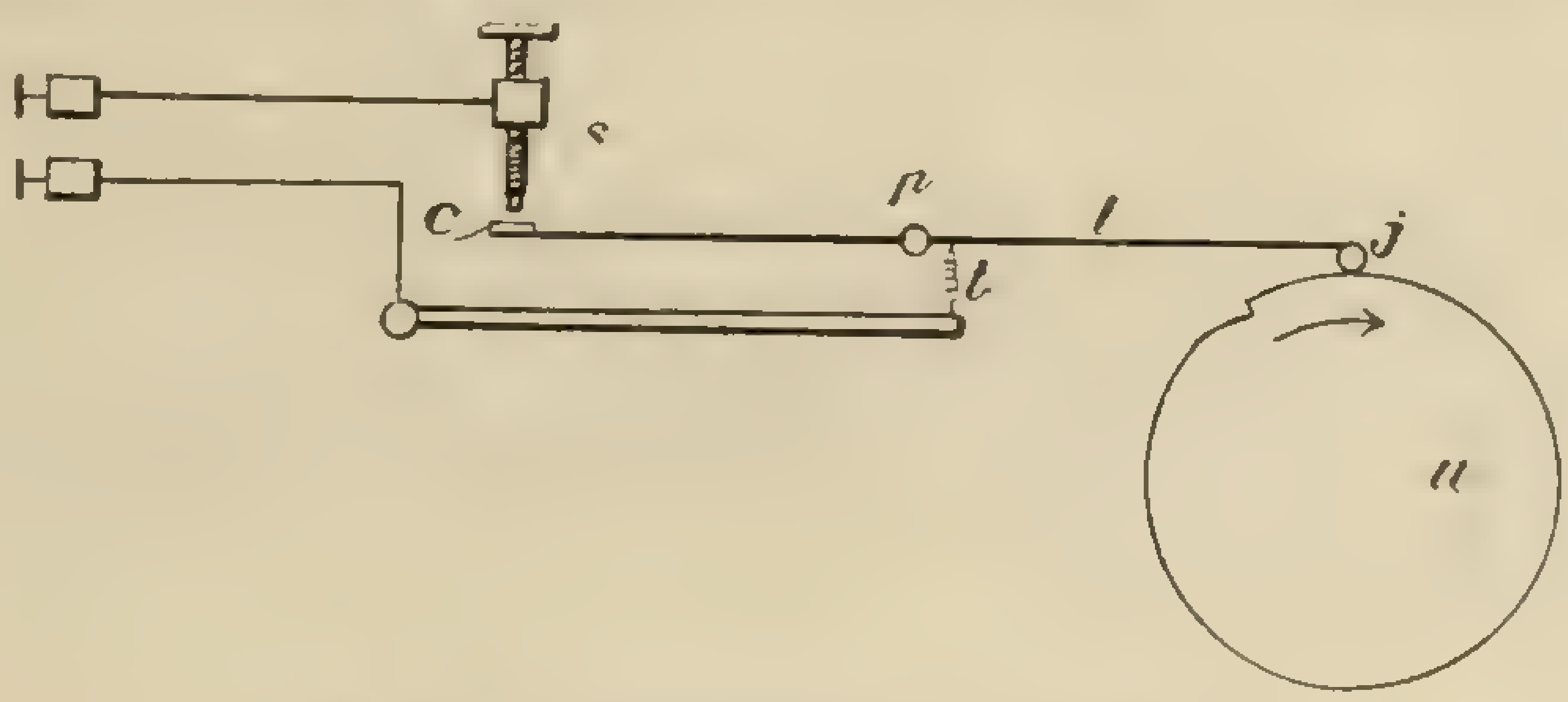


Fig. 3.—Minute contact (old style).

ment building; the remaining one will be completed shortly. Fig. 3 shows the principle of the original contact; the contact wheel w, containing a single slot, revolves once a minute with the arbor of the escapement wheel; the contact lever l, pivoted at p, carries a jewel j at one end and a contact piece c at the other; as the wheel revolves the circuit is closed for one second each minute between c and the adjustable contact screw s; the tension is regulated by the spring t. The difficulty with this contact was that a tension sufficient to give a firm contact at c involved a considerable downward pressure, and consequent friction, on the contact wheel, especially at the instant when j was being raised out of the slot; to make matters worse, the contact wheel was so large that this friction exerted considerable leverage on the clock-train. The effect was, that a firm contact was impossible without risk of stopping the clock. A diagram of the new contacts installed is shown in fig. 4. The contact wheel is replaced by a

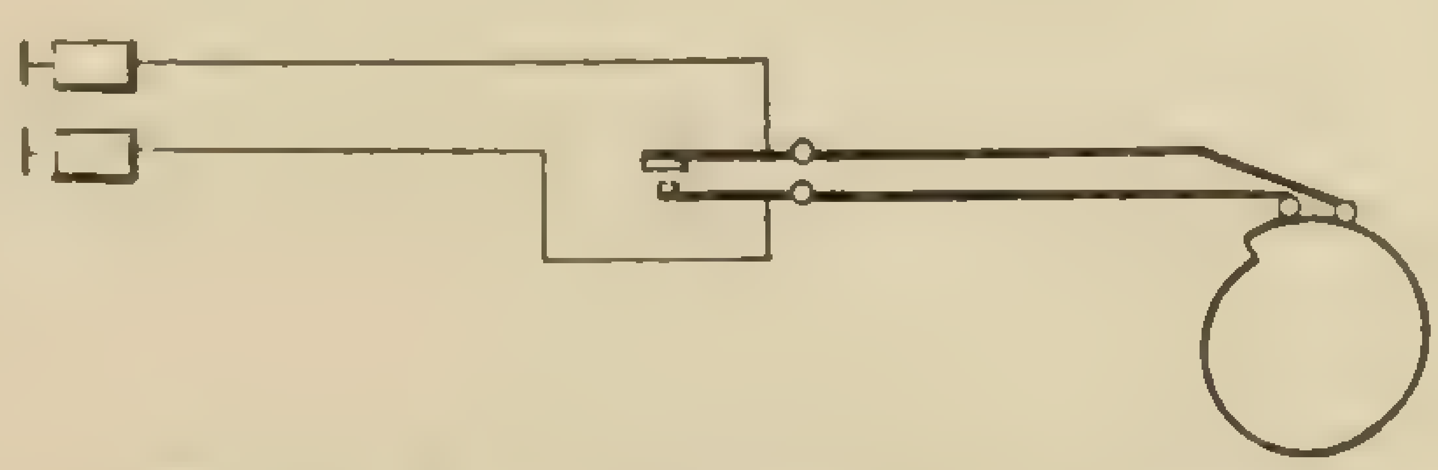


Fig. 4.—Minute contact (new style).

small cam, and the contact lever by two separate ones, one running slightly in advance of the other on the cam; the tail-pieces, where the contact is made, are comparatively short, so that the pressure at the contact ends of the levers is much greater than on the cam; in addition, the work done by the cam in raising the levers is distributed

throughout nearly the whole revolution. The contact is closed at the 59th second by the dropping of the first lever, and reopened at the 60th by the dropping of the second. Since their installation these contacts have worked in a perfectly satisfactory manner.

The relays worked by these contacts, which control the dial circuits, were formerly equipped with a mercury break at the points, because some previous experiments had shown that with platinum points, unless with a relay which worked very strongly, the sparking at the points was liable to cause trouble. The relays in use, however, were fairly strong, and after the installation of the new contacts their action was firm and certain; as platinum points require less attention than mercury ones, where their use is possible, the experiment of installing them was tried first in one building, and proving successful, their use was adopted throughout. The mercury points have, however, been retained in the cut-out relays for the charging circuits, as they are required to control a stronger current.

There is very seldom now any trouble arising from dials stopping or becoming deranged, unless through unwarranted interference. On several occasions this has occurred; for instance, an officer in one of the departments, claiming to be annoyed by the ticking of the dial, instructed a messenger to remove it; this was done, and the circuit left open, with the obvious result of stopping all the dials on that circuit. In another case, when a dial had been removed from a certain room, the wires were left temporarily in place, pending the proper connection and insulation in the corridor outside; shortly after, a complaint was received from that building that the dials had stopped; investigation showed that the wires in the room had been deliberately cut and taken down. The circuits have also on several occasions been broken by careless or ignorant workmen. In addition, it is of course sometimes to be expected that an isolated dial will get out of order and either stop or fall behind; in that case it is desirable that the observatory should be immediately notified and the matter will receive prompt attention. The precaution is taken as frequently as possible of inspecting each separate clock; this work, and also the other necessary attention, such as recharging batteries and winding master-clocks, is performed almost altogether by Mr. Robertson of the observatory staff.

I have the honour to be, sir,
Your obedient servant,

R. M. STEWART.

APPENDIX 4

REPORT OF THE CHIEF ASTRONOMER.

TABULAR STATEMENT OF LONGITUDE AND LATITUDE OBSERVATIONS, 1905

BY

J. MACARA.

CONTENTS.

APPENDIX 4.

TABULAR STATEMENT OF LONGITUDE AND LATITUDE OBSERVATIONS.

OTTAWA, ONT., August 16, 1906.

W. F. KING, Esq., B.A., LL.D.,
Chief Astronomer,
Ottawa.

SIR,—I have the honour to transmit herewith a tabular statement of the differences of longitude and the latitude results of stations observed in 1905. Annexed thereto is, also, a description of the stations occupied.

A synopsis of the statement giving the longitude and latitude of the various stations will be found on page 129.

I have the honour to be, sir,
Your obedient servant,

J. MACARA.

DIFFERENCE OF LONGITUDE BETWEEN CLIFF ST. TRANSIT HOUSE AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	m. s.	s.	s.	s.	s.	s.	s.	s.
May 26..	3 37·479	3 37·491	1 25·682	± ·007	2 09·974	± ·006	1·823	1·835	1·829	± ·009	− ·006	·006
" 27....	3 48·875	3 48·872	1 25·061	± ·008	2 22·024	± ·009	1·790	1·787	1·788	± ·012	− ·047	·001
" 28 ...	3 59·446	3 59·436	1 24·374	± ·010	2 33·197	± ·007	1·875	1·865	1·870	± ·012	+ ·035	·005
" 31....	4 34·201	4 34·211	1 22·381	± ·011	3 10·062	± ·009	1·838	1·848	1·843	± ·014	+ ·008	·005
June 3....	5 09·302	5 09·304	1 20·152	± ·012	3 47·293	± ·008	1·857	1·859	1·858	± ·014	+ ·023	·001

	h.	m.	s.		s.
Weighted mean..............			1·835	±	·005
Personal equation.............			− ·096	±	·007
$d\lambda$..........................			1·739	±	·009
λ Cliff Street transit house.....	5	02	50·022	±	·051
∴ λ Dominion Observatory......	5	02	51·761	±	·052

Observers:—West, R. M. Stewart.
East, F. A. McDiarmid.

DIFFERENCE OF LONGITUDE BETWEEN VANCOUVER AND SEATTLE.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.		s.	s.
June 1 . . .	2 17·676	2 17·577	1 30·248	± ·023	−39·601	± ·014	3 08 323	3 08·224	3 08·273	. . . .	+ ·086	·050
" 7	2 36·155	2 36·012	− 1 13·526	± ·010	−41·453	± ·016	3 08·228	3 08·087	3 08·157	. . . .	− ·030	·071
" 8 . .	2 38·758	2 38·632	− 1 11·034	± ·017	−41·662	± ·020	3 08·130	3 08·004	3 08·067	. . . .	− ·120	·063
" 9 . .	2 41·773	2 41·651	− 1 08·334	± ·014	−41·866	± ·026	3 08·241	3 08·119	3 08·180	. . . .	− ·007	·061
" 13	2 53·855	2 53·727	0 57·950	± ·017	−43·545	± ·012	3 08·260	3 08·132	3 08·196	. . . .	+ ·009	·066
" 14	2 57·434	2 57·316	− 0 54·740	± ·012	−43·886	± ·013	3 08·288	3 08·170	3 08·229	. . . . . .	+ ·042	·066

	h.	m.	s.
Weighted mean	0	03	08 187
λ Seattle	8	09	20·274
λ Vancouver	8	12	28·461

OBSERVERS:—West, O. J. KLOTZ.
East, E. SMITH.

DIFFERENCE OF LONGITUDE BETWEEN SHARBOT LAKE AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
June 14...	3 09·757	3 09·691	– 43·283	± ·007	1·076	± ·007	3 54·116	3 54·050	3 54·083	± ·010	+ ·065	·033
" 15...	3 01·611	3 01·563	– 51·037	± ·008	1·376	± ·007	3 54·024	3 53·976	3 54·000	± ·010	– ·018	·024
" 22...	4 19·619	4 19·580	– 28·393	± ·006	2·755	± ·010	3 53·981	3 53·942	3 53·961	± ·011	– ·057	·020

	h.	m.	s.		s.
Weighted mean...		3	54·018	±	·006
Personal equation...			·120	±	·006
$d\lambda$...		3	54·138	±	·008
λ Ottawa...	5	02	51 761	±	·052
∴ λ Sharbot Lake...	5	06	45·899	±	·052

Observers:—West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN ST. ANNE DE BELLEVUE AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	s.	s.	m. s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
June 29...	9 16·194	9 16·170	3·315	± ·008	− 2 09·160	± ·006	7 03·719	7 03·695	7 03·707	± ·010	+ ·017	·012
" 29...	9 17·015	9 17·010	3·301	± ·013	− 2 10·021	± ·006	7 03·694	7 03·689	7 03·692	± ·014	+ ·002	·003
" 30...	9 25·961	9 25·921	3·427	± ·008	− 2 18·850	± ·009	7 03·684	7 03·644	7 03·664	± ·012	− ·026	·020

	h.	m.	s.		s.
Weighted mean		7	03·690	±	·007
Personal equation			− ·139	±	·008
$d\lambda$		7	03·551	±	·010
λ Ottawa	5	02	51·761	±	·052
∴ λ St. Anne de Bellevue	4	55	48·210	±	·053

Observers :—West, R. M. Stewart.
East, F. A. McDiarmid.

DIFFERENCE OF LONGITUDE BETWEEN TRENTON AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph. Western Signals.	Difference of Chronograph. Eastern Signals.	Clock Correction. Western Station.	Clock Correction. Probable Error.	Clock Correction. Eastern Station.	Clock Correction. Probable Error.	Difference of Longitude. Western Signals.	Difference of Longitude. Eastern Signals.	Difference of Longitude. Mean.	Difference of Longitude. Probable Error.	Difference of Longitude. v.	Time of Transmission.
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
July 8....	6 16·536	6 16·445	− 1 06·339	± ·008	3·935	± ·007	7 26·810	7 26·719	7 26·764	± ·010	− ·006	·045
" 10....	5 59·057	5 58·955	− 1 23·692	± ·008	4·075	± ·008	7 26·824	7 26·722	7 26·773	± ·011	+ ·003	·051
" 12 ...	5 44·247	5 44·163	− 1 38·281	± ·007	4·270	± ·011	7 26·798	7 26·714	7 26·756	± ·013	− ·014	·042
" 14....	5 30·125	5 30·060	− 1 52·248	± ·008	4·470	± ·016	7 26·843	7 26·778	7 26·811	± ·018	+ ·041	·033

	h.	m.	s.		s.
Weighted mean..		7	26·770	±	·006
Personal equation... ...			·151	±	·008
$d\ \lambda$....		7	26·921	±	·010
λ Ottawa..	5	02	51·761	±	·052
∴ λ Trenton............	5	10	18·682	±	·053

Observers:—West, E. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN MADOC AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
July 17 ..	7 38·317	7 38·231	41·093	± ·010	4·613	± ·014	7 01·837	7 01·751	7 01·794	± ·017	− ·039	·043
" 19....	7 39·454	7 39·376	42·322	± ·010	4·691	± ·013	7 01·823	7 01·745	7 01·784	± ·016	− ·049	·039
" 20....	7 36·306	7 36·174	39·101	± ·007	4·730	± ·008	7 01·935	7 01·803	7 01·869	± ·011	+ ·036	·066
" 21 ..	7 30·112	7 29·924	32·821	± ·010	4·641	± ·010	7 01·932	7 01·744	7 01·838	± ·014	+ ·005	·094

	h.	m.	s.		s.
Weighted mean		7	01·833	±	·007
Personal equation			·162	±	·009
$d\lambda$		7	01·995	±	·011
λ Ottawa	5	02	51·761	±	·052
∴ λ Madoc	5	09	53·756	±	·053

Observers: West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN FATHER POINT AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905	m. s.	m. s.	s.	s.	m. s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
July 14....	30 26·095	30 25·960	4·475	± ·016	−1 22·946	± ·010	28 58·674	28 58·539	28 58·601	± ·018	·076	·067
" 15 .	30 22·987	30 22·850	4·584	± ·008	−1 19·805	± ·006	28 58·598	28 58·461	28 58·530	± ·010	·005	·069
" 17 ...	30 16·437	30 16·305	4·612	± ·014	−1 13·274	± ·007	28 58·551	28 58·419	28 58·485	± ·016	− ·040	·066
" 20....	30 06·878	30 06·766	4·746	± ·009	−1 03·588	± ·012	28 58·544	28 58·432	28 58·488	± ·015	− ·037	·056
" 21...	30 03·032	30 02·883	4·667	± ·011	−0 59·738	± ·019	28 58·627	28 58·478	28 58·557	± ·026	·032	·074

	h.	m.	s.		s.
Weighted mean..........		28	58·525	±	·007
Personal equation....			− ·337	±	·006
$d\ \lambda$..........................		28	58·188	±	·009
λ Ottawa	5	02	51·761	±	·052
∴ λ Father Point.....	4	33	53·573	±	·052

Observers: West, R. M. Stewart.
East, O. J. Klotz.

DIFFERENCE OF LONGITUDE BETWEEN LINDSAY AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
July 25....	15 14·091	15 14·012	3 13·907	± ·008	4·596	± ·015	12 04·780	12 04·701	12 04·740	± ·017	+ ·041	·040
" 27 ...	14 51·506	14 51·403	2 51·348	± ·014	4 586	± ·010	12 04·744	12 04·641	12 04·692	± ·017	+ ·013	·052
" 28 ...	14 41·791	14 41·692	2 41·711	± ·008	4·616	± ·009	12 04·696	12 04·597	12 04 642	± ·012	− ·037	·049

	h.	m.	s.		s.
Weighted mean..............		12	04·679	±	·008
Personal equation...........			·169	±	·009
$d\lambda$..........................		12	04·848	±	·012
λ Ottawa...................	5	02	51 761	±	·052
∴λ Lindsay.................	5	14	56·609	±	·053

Observers: West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN KINGSTON AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Aug. 2....	− 0 53·774	0 53·891	− 3 50·973	± ·006	3·775	± ·006	3 00·974	3 00·858	3 00·916	± ·009	+ ·014	·058
" 3...	− 1 03·607	1 03·663	− 4 00·929	± 009	3·640	± ·008	3 00·962	3 00·906	3 00·934	± ·012	+ ·032	·028
" 6....	− 1 29·547	1 29·707	− 4 27·151	± ·009	3·367	± ·012	3 00 971	3 00·811	3 00·891	± ·015	− ·011	·080
" 8....	− 1 46·370	1 46·485	− 4 43·926	± 008	3·331	± ·008	3 00·887	3 00·772	3 00·830	± ·011	− ·072	·058
" 10 ...	− 2 01·523	2 01·654	− 4 59·367	± ·011	3·103	± ·010	3 00·947	3 00·816	3 00·882	± ·015	− ·020	·065

	h.	m.	s.		s.
Weighted mean		3	00 902	±	·005
Personal equation			·180	±	·069
$d\lambda$...		3	01·082	±	·010
λ Ottawa	5	02	51·761	±	·052
$\therefore \lambda$ Kingston.......	5	05	52·843	±	·053

Observers :—West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN TADOUSAC AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Aug. 8....	24 09·484	24 09·284	3·330	± ·008	- 5·469	± ·011	24 00·685	24 00·485	24 00·585	± ·013	- ·002	·100
" 10...	24 02·358	24 02·143	3·090	± ·011	1·480	± ·009	24 00·748	24 00·533	24 00·640	± ·014	·053	·107
" 13....	23 54·156	23 54·000	3·385	± ·010	9·834	± ·012	24 00·605	24 00·449	24 00·527	± ·015	- ·060	·078
" 14....	23 50·792	23 50·604	3·449	± ·008	13·255	± ·012	24 00·598	24 00·410	24 00·504	± ·015	- ·083	·094

	h.	m.	s.		s.
Weighted mean		24	00·587	±	·007
Personal equation			- ·337	±	·006
$d\lambda$		24	00·250	±	·009
λ Ottawa	5	02	51·761	±	·052
∴ λ Tadousac	4	38	51·511	±	·052

Observers :—West, R. M. Stewart.
East, O. J. Klotz.

DIFFERENCE OF LONGITUDE BETWEEN WHITBY AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Tran mission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Aug. 16...	11 01·022	11 00·937	− 1 49·359	± ·014	3·640	± ·010	12 54·021	12 53·936	12 53·979	± ·017	+ ·111	·043
" 17...	10 49·835	10 49·755	− 2 00·501	± ·008	3·539	± ·009	12 53·875	12 53·795	12 53·835	± ·012	·033	·040
" 18...	10 38·412	10 38·322	− 2 11·797	± ·010	3·678	± ·009	12 53·887	12 53·797	12 53·842	± ·013	− ·026	·045

	h.	m.	s.		s.
Weighted mean		12	53·868	±	·007
Personal equation............			·197	±	·010
$d\lambda$....................		12	54·065	±	·012
λ Ottawa..................	5	02	51·761	±	·052
∴ λ Whitby..................	5	15	45·826	±	·053

Observers:—West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN SUTTON AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Aug. 22...	12 10·694	12 10·557	− 2 21·566	± ·008	3·481	± ·009	14 35·741	14 35·604	14 35·672	± ·012	+ ·041	·068
" 25..	11 36·684	11 36·548	− 2 55·546	± ·011	3·452	± ·010	14 35·682	14 35·546	14 35·614	± ·015	− ·017	·068
" 25...	11 36·009	11 35·890	− 2 56·186	± ·011	3·416	± ·008	14 35·641	14 35·492	14 35·552	± ·014	− ·079	·060

	h.	m.	s.	s.
Weighted mean		14	35·631	± ·008
Personal equation.			·203	± ·010
$d\lambda$		14	35·834	± ·013
λ Ottawa	5	02	51·761	± ·052
∴ λ Sutton	5	17	27·595	± ·053

Observers :—West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN ST. CATHARINES AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
August 29.	13 25·476	13 25·380	−35·841	± ·008	3·698	± ·010	14 05·015	14 04·919	14 04·967	± ·013	− ·027	·048
" 31.	13 08·430	13 08·364	−52·929	± ·008	3·639	± ·013	14 04·998	14 04·934	14 04·966	± ·015	− ·028	·033
Sept. 1.	12 58·920	12 58·845	−1 02·432	± ·007	3·703	± ·006	14 05·055	14 04·980	14 05·017	± ·009	+ ·023	·038

	h.	m.	s.		s.
Weighted mean		14	04·994	±	·007
Personal equation			·219	±	·010
$d\lambda$		14	05·213	±	·012
λ Ottawa	5	02	51·761	±	·052
∴ λ St. Catharines	5	16	56·974	±	·053

Observers:—West, F. A. McDiarmid,
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN HARVARD COLLEGE AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	s.	s.	m. s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Aug. 31...	18 08·746	18 08·565	3·642	± ·013	0 15·791	± ·010	18 20·895	18 20·714	18 20·805	± ·016	– ·075	·091
Sept. 5...	17 56·582	17 56·409	3·502	± ·010	0 27·928	± ·014	18 21·002	18 20·835	18 20·918	± ·017	·038	·083
" 8...	17 48·535	17 48·370	3·387	± ·006	0 35·801	± ·010	18 20·949	18 20·784	18 20·866	± ·011	– ·014	·082
" 9...	17 45·666	17 45·518	3·369	± ·006	0 38·670	± ·011	18 20·967	18 20·819	18 20·893	± ·013	·013	·074
" 10...	17 43·097	17 42·909	3·536	± ·006	0 41·413	± ·016	18 20·974	18 20·786	18 20·880	± ·017	·000	·094
" 14...	17 33·109	17 32·927	3·504	± ·010	0 51·396	± ·013	18 21·001	18 20·819	18 20·910	± ·016	·030	·091
" 21...	17 12·872	17 12·740	2·200	± ·006	1 10·292	± ·018	18 20·964	18 20·832	18 20·898	± ·018	·018	·066

	h.	m.	s.		s.
Weighted mean		18	20·880	±	·006
Personal equation			– ·337	±	·006
$d\lambda$....		18	20·543	±	·008
λ Harvard College................	4	44	31·160		
λ Ottawa.........................	5	02	51·703		

Observers :—West, R. M. Stewart.
East, O. J. Klotz.

DIFFERENCE OF LONGITUDE BETWEEN NORTH BAY AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Sept. 27...	14 18·301	14 18·239	−40·059	± ·011	·512	± ·010	14 58·872	14 58·810	14 58·841	± ·015	+ ·004	·031
" 28...	14 14·496	14 14·402	−44·082	± ·006	·314	± ·005	14 58·893	14 58·789	14 58·846	± ·008	+ ·009	·047
" 29...	14 10·902	14 10·819	−47·905	± ·007	·049	± ·006	14 58·856	14 58·773	14 58·815	± ·009	− ·022	·042

	h.	m.	s.		s.
Weighted mean		14	58·837	±	·006
Personal equation.			·242	±	·011
$d\lambda$..........		14	59·079	±	·012
λ Ottawa	5	02	51·761	±	·052
$\therefore\lambda$ North Bay	5	17	50·840	±	·053

Observers: West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN TEMAGAMI AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph. Western Signals.	Difference of Chronograph. Eastern Signals.	Clock Correction. Western Station.	Clock Correction. Probable Error.	Clock Correction. Eastern Station.	Clock Correction. Probable Error.	Difference of Longitude. Western Signals.	Difference of Longitude. Eastern Signals.	Difference of Longitude. Mean.	Difference of Longitude. Probable Error.	Difference of Longitude. r.	Time of Transmission.
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
October 3..	17 31·089	17 30·994	1 12·888	± ·007	−0·901	± ·008	16 17·300	16 17·205	16 17·252	± ·011	− ·016	·047
" 5..	17 26·957	17 26·816	1 08·279	± ·008	−1·306	± ·009	16 17·372	16 17·231	16 17·301	± ·012	+ ·033	·070
" 6..	17 25·416	17 25·306	1 06·545	± ·012	−1·525	± ·013	16 17·346	16 17·236	16 17·292	± ·018	+ ·024	·056
" 6..	17 25·299	17 25·215	1 06·471	± ·012	−1·535	± ·009	16 17·293	16 17·209	16 17·251	± ·015	− ·017	·042

	h.	m.	s.		s.
Weighted mean		16	17·268	±	·006
Personal equation			·251	±	·011
$d\ \lambda$		16	17·519	±	·012
λ Ottawa	5	02	51·761	±	·052
$\therefore \lambda$ Temagami	5	19	09·280	±	·053

Observers: West, F. A. McDiarmid.
East, R. M. Stewart.

DIFFERENCE OF LONGITUDE BETWEEN RENFREW AND DOMINION OBSERVATORY, OTTAWA.

Date.	Difference of Chronograph.		Clock Correction.				Difference of Longitude.					Time of Transmission.
	Western Signals.	Eastern Signals.	Western Station.	Probable Error.	Eastern Station.	Probable Error.	Western Signals.	Eastern Signals.	Mean.	Probable Error.	v.	
1905.	m. s.	m. s.	m. s.	s.	s.	s.	m. s.	m. s.	m. s.	s.	s.	s.
Oct. 14....	3 10·192	3 10·099	− 0 43·952	± ·010	− 2·510	± ·009	3 51·634	3 51·541	3 51·588	± ·014	− ·067	·046
" 21....	2 40·075	2 39·993	− 1 14·963	± ·010	− 3·332	± ·009	3 51·706	3 51·623	3 51·664	± ·014	+ ·009	·041
" 25....	2 22·966	2 22·916	− 1 32·472	± ·010	− 3·699	± ·009	3 51·739	3 51·689	3 51·714	± ·014	+ ·059	·025

	h.	m.	s.		s.
Weighted mean................		3	51·655	±	·008
Personal equation............			·275	±	·011
$d\ \lambda$..........................		3	51·930	±	·013
λ Ottawa	5	02	51·761	±	·052
∴ λ Renfrew	5	06	43·691	±	·053

Observers:—West, F. A. McDiarmid,
East, R. M. Stewart,

LONGITUDE AND LATITUDE OF STATIONS OBSERVED IN 1905.

Place.	Difference of Longitude.		To	Longitude.		Longitude.		Latitude.	
	m. s.	s.		h. m. s.	s.	° ′ ″	″	° ′ ″	″
Dominion Observatory	1·739	± ·009	Cliff St. transit house	5 02 51·761	± ·052	75 42 56·41	± ·78		
Vancouver	3 08·187	±	Seattle	8 12 28·461		123 07 06·91			
Sharbot Lake	3 54·138	± ·008	Dominion Observatory	5 06 45·899	± ·052	76 41 28·48	± ·78	44 46 29·07	± ·13
Ste. Anne de Bellevue	7 03·551	± ·010	" "	4 55 48·210	± ·053	73 57 03·15	± ·80	45 24 28·13	± ·09
Trenton	7 26·921	± ·010	" "	5 10 18·682	± ·053	77 34 40·23	± ·80	44 05 52·53	± ·09
Madoc	7 01·995	± ·011	" "	5 09 53·756	± ·053	77 28 26·34	± ·80	44 30 15·70	± ·15
Father Point	28 58·188	± ·009	" "	4 33 53·573	± ·052	68 28 23·60	± ·78	48 31 05·14	± ·20
Lindsay	12 04·848	± ·012	" "	5 14 56·609	± ·053	78 44 09·13	± ·80	44 21 30·50	± ·12
Kingston	3 01·082	± ·010	" "	5 05 52·843	± ·053	76 28 12·64	± ·80	44 13 46·58	± ·09
Tadousac	24 00·250	± ·009	" "	4 38 51·511	± ·052	69 42 52·67	± ·78	48 08 27·19	± ·12
Whitby	12 54·065	± ·012	" "	5 15 45·826	± ·053	78 56 27·39	± ·80	43 52 43·34	± ·12
Sutton	14 35·834	± ·013	" "	5 17 27·595	± ·053	79 21 53·92	± ·80	44 18 12·49	± ·12
St. Catharines	14 05·213	± ·012	" "	5 16 56·974	± ·053	79 14 14·61	± ·80	43 09 41·72	± ·13
Dominion Observatory	18 20·543	± ·008	Harvard College	5 02 51·703		75 42 55·55			
North Bay	14 59·079	± ·012	Dominion Observatory	5 17 50·840	± ·053	79 27 42·60	± ·80	46 18 22·21	± ·10
Temagami	16 17·519	± ·012	" "	5 19 09·280	± ·053	79 47 19·20	± ·80	47 03 47·91	± ·10
Renfrew	3 51·930	± ·013	" "	5 06 43·691	± ·053	76 40 55·36	± ·80	45 28 30·08	± ·14

LOCAL POSITIONS OF ASTRONOMICAL STATIONS.

Dominion Observatory.—The reference point of the longitudes observed in 1905 is a temporary transit house, the meridian of which is $0^s \cdot 12$ east of the centre of the dome of the observatory.

Vancouver.—The observatory is at Brockton Point, in Stanley Park.

Sharbot Lake.—The observatory was on a hill north of the Canadian Pacific Railway station. The pier is 385 feet north and 73·5 feet west of the west corner of the Canadian Pacific Railway station house.

Ste. Anne de Bellevue.—The observatory was about 300 feet south of the Canadian Pacific Railway station. The pier is 1552·22 feet N. 12° 12′ 15″ E. from main triangulation station 5 on end of guard pier at the lower entrance of the new lock.

Trenton.—The observatory was on the right-of-way of the Central Ontario Railway. The pier is 173 feet south and 83 feet east of the southeast corner of the Central Ontario Railway station house.

Madoc.—The pier is 113 feet west and 123 feet north of the northwest corner of Durham and St. Lawrence streets.

Father Point.—The observatory was on the property of J. McWilliams, immediately adjoining the lighthouse reserve. The centre of the pier is 125 feet 7 inches due south of the centre of the revolving light surmounting the lighthouse.

Lindsay.—The observatory was on the right-of-way of the Canadian Pacific Railway, 10·7 feet west and 172·8 feet north of the northwest corner of the Canadian Pacific Railway station house.

Kingston.—The observatory is situated on the Royal Military College grounds, on Point Frederick, about 200 feet from Cataraqui bay. It is used in connection with the work of the college.

Tadousac.—The observatory was on the premises of the Richelieu and Ontario Navigation Company, to the rear of their hotel. The meridian through the centre of the pier passes one foot west of the flag-pole over the tower of the main or office entrance to the hotel, and the flag-pole is 211 feet south of the pier.

Whitby.—The pier is 198 feet north and 159·3 feet east of the northeast corner of Brock and Colborne streets.

Sutton.—The observatory was situated on the right-of-way of the Grand Trunk Railway. The pier is 65·7 feet south and 111·2 feet west of the southwest corner of the Grand Trunk Railway station house.

St. Catharines.—The observatory was situated on the property of the St. Catharines Gas Company, at the corner of Phelps and Mill streets. The pier is 191·5 feet north and 94 feet east of the northeast corner of Phelps and Mill streets.

North Bay.—The observatory was situated on the property of the Canadian Pacific Railway. The pier is 283·5 feet south and 109·5 feet west of the northwest corner of Main and Sherbrooke streets.

Temagami.—The observatory was situated on the right-of-way of the Temiskaming and Northern Ontario Railway. The pier is 316 feet south and 219·6 feet west of the southwest corner of the Temiskaming and Northern Ontario Railway station house.

Renfrew.—The observatory was situated north of the Canadian Pacific Railway station, about 210 feet north of the main line. The pier is 75 feet north and 77·7 feet east of the southwest corner of Joe and Janet streets.

APPENDIX 5

REPORT OF THE CHIEF ASTRONOMER.

GEOLOGY OF THE MOUNTAINS CROSSED BY THE INTERNATIONAL BOUNDARY (49TH PARALLEL)

BY

R. A. DALY, PH.D.

APPENDIX 5.

REPORT ON FIELD OPERATIONS IN THE GEOLOGY OF THE MOUNTAINS CROSSED BY THE INTERNATIONAL BOUNDARY (49TH PARALLEL).

By R. A. Daly, Ph.D.

Ottawa, Ont., November 14, 1906.

W. F. King, Esq., LL.D., D.T.S., &c.,
International Boundary Commissioner,
Ottawa.

Sir,—I have the honour to transmit herewith a brief report of my work as geologist to the Boundary Commission during the past year.

The field-season of 1906 was largely spent in completing the geological map and structure section across the mountains along the 49th parallel of latitude. After the preceding seasons of employment on this work there remained three short belts to be surveyed.

One of these areas lies between Christina lake and Midway. The larger part of this belt, extending fifteen miles along the boundary east of Midway, had already been surveyed in detail by Mr. R. W. Brock of the Geological Survey Department. It seemed inadvisable to cover the ground thoroughly again, and I merely traversed this part of the belt to become acquainted with the formational units mapped by Mr. Brock, and to effectively tie on his map at its two ends to the general boundary map. It was a pleasure to appreciate by actual field tests, the excellence of his mapping in this, geologically very difficult, piece of country.

Between Christina lake and Grand Forks, a belt ten miles long from east to west and five miles in width was mapped. This area lies outside of the Boundary District map of Mr. Brock, and was surveyed in detail. The geology proved to be here, in the main, simple, as most of the area is underlain by a batholith of greatly crushed granite, now for the most part a banded gneiss. This batholith is structurally and genetically a parallel to the Remmel and Osoyoos granite batholiths examined last year, and already described in a paper on the Okanagan Composite Batholith.

The second area studied extends from the Skagit river to Chilliwack lake—a belt sixteen miles long and five miles or more in width. Its mapping has thus filled the gap in the general boundary map between the belts covered in the respective seasons of 1901 and 1905. The oldest formation found is a thick metamorphic series of unfossiliferous, but probably Palæozoic sedimentary rocks, now occurring as normal quartzites, cherty quartzites, phyllites and other micaceous schists ; the whole group corresponds in many features to the Carboniferous Cache Creek series. These metamorphic rocks are cut by a greatly sheared and banded gneissic granite of batholithic relations. Its intrusion is tentatively referred to the Jurassic period. Both the granite and the invaded sedimentary rocks were deeply eroded and were then unconformably covered by a thick series of basic volcanic flows, breccias and tuffs. The volcanics have low dips, but are extensively faulted; they are tentatively correlated with the volcanic breccias of similar composition underlying the Lower Cretaceous Pasayten formation mapped last season in the adjoining Hozomeen range. The youngest principal formation is the Tertiary batholith of granodiorite described in 1901 as composing the moun-

tains surrounding Chilliwack lake. The whole belt between the lake and the Skagit river is extremely rugged, the volcanic formation noted composing the high, sometimes almost inaccessible, peaks along the summit of Skagit range.

The third area covered this season extends from Slesse creek to Sumas prairie, a distance of about twenty miles from east to west. The minimum width of this belt is five miles. The region has only recently become accessible; by means of Mr. McArthur's system of good trails it is now possible, for the first time, to take horses and supplies into the heart of the region. Without such trails it would have been impossible to do satisfactory geological work in this most inaccessible part of the whole international boundary. The work has consisted chiefly in the attempt to unravel the complex groups of strata which here compose the Pacific slope of the Cascade range. A large part of the season of 1901 was spent on these same rocks, and, at that time, Palæozoic fossils were discovered in some of the staple formations; but many of their problems of stratigraphy and of correlation remained absolutely unsolved. It was therefore a matter of gratification to find fossils at half a dozen points and in critical members of the stratified series. The fossils indicate that both Mesozoic and Palæozoic formations are present. When a detailed determination of the collections has been made, it is hoped that these rocks may be referred to particular stratigraphic horizons. Associated with the Mesozoic sediments, which are argillites chiefly, is a thick, massive series of vesicular flows of basic lavas now greatly crushed, faulted and metamorphosed; they are tentatively correlated with the Triassic volcanics of Vancouver island and Queen Charlotte islands.

After the mapping of this third area, a week was spent in the study of the fossiliferous Cambrian rocks described by Mr. McConnell as occurring along the main line of the Canadian Pacific Railway. The purpose of the study was to test the conclusion derived from the field data of 1905, that a large part of the conformable series composing the staple rocks of the Southern Selkirk system, the Purcell system, and the Rocky Mountain system at the forty-ninth parallel, are also Cambrian, though they bear no determinable fossils. It was found that the Castle Mountain-Bow River Cambrian strata repeat with great fidelity a large number of special lithological features characteristic of the great Siyeh formation and the underlying formations at the boundary. These special correspondences render it in the highest degree probable that the base of the Cambrian underlies the Siyeh formation, while, of course, overlying the pre-Cambrian Altyn limestone in which 'Algonkian' fossils were discovered in 1905. It has thus become possible to correlate with considerable certainty the dominant sedimentary formations of the eastern half of the boundary belt with the major sub-divisions of the world's geological series. The 4,000-foot dolomitic and argillitic Siyeh formation is the stratigraphic equivalent of the massive Castle Mountain group of dolomites and argillites; the correlation of other formations in the boundary sections will be detailed in the final report.

Since the Cambrian and pre-Cambrian rocks of the boundary belt and elsewhere in British Columbia, Alberta, Idaho and Montana, are relatively not much metamorphosed, the prevailing absence of fossils in those rocks has itself afforded an important special problem antecedent to the interpretation of the rocks in the different sections. I have attempted a solution of the problem in terms of the varying constitution of ocean-water. The conclusion arrived at is, briefly, that the pre-Cambrian Ocean, for most of its history, was practically a limeless ocean. It was not until near the beginning of Lower Cambrian time that calcium salts came to be dissolved in the sea-water in amounts sufficient for the needs of lime-secreting organisms. The oceanic condition for the preservation of abundant animal remains became established only in late Cambrian or in Silurian time. The hypothesis further explains the origin of magnesian sediments including dolomites, and suggests the origin of many iron ore deposits as, for example, those of the Lake Superior district. An explanation is also offered of the emanations of natural gas and petroleum from the pre-Cambrian rocks of the Flathead valley, on which I reported last year. This hypothesis has been outlined in the form of a special paper and is now in press.

As in former years the effort was made during the months in the office, to clear up some of the theoretical and other major difficulties in the way of the interpretation of field observations in the boundary mountains. The experience of the five seasons spent on the boundary work have convinced me more and more thoroughly that theoretical geology is the basis of practical geology, that economic or mining geology is unceasingly dependent on the healthy and vigorous growth of the theory of general physical geology. On the other hand, the data for intelligent geological theory must be found chiefly in sheet or areal mapping on the large scale. There is, therefore, one principal way in which the Government can best subserve the interests of the mining public, and that is, by causing the active, thorough, interpreting geological survey of areas much larger than mining districts. That wider view of the rocks is absolutely indispensable to a full and rounded, and hence completely fruitful knowledge of ore-bodies or other mineral deposits as to their origin, occurrence or exploitation. The mining companies are to-day showing an increasing demand for the services of those mining geologists who have most completely assimilated the stable principles of rock-interpretation laid down by intelligent areal geologists. Both classes of geologists are dependent upon theory; without theory it is impossible to take a single long step in the explanation of field phenomena whether those have a direct practical bearing or not. It is thus not of choice merely, but of necessity, that I have had to spend much time on the theoretical side of the boundary geology.

A paper on 'Abyssal Igneous Injection as a Causal Condition and as an Effect of Mountain-Building' was published in the September number of the *American Journal of Science*. A second paper on 'The Differentiation of a Secondary Magma through Gravitative Adjustment' was published at Stuttgart in the *Rosenbusch Festschrift*. A third on 'The Okanagan Composite Batholith of the Cascade Mountain System' was published among the bulletins of the Geological Society of America, volume 17. A fourth paper, on 'The Nomenclature of the North American Cordillera between the 47th and 53rd Parallels of Latitude' was printed in the June number of the *Geographical Journal.*

These publications and the continued preparation of the final report on the boundary geology occupied all of the year except the time spent in the field and in attending the International Geological Congress in Mexico City during the middle part of September.

With the close of the past season the field work has been practically completed for the geological map and sections across the mountains. Owing to the exigencies of the work, and especially owing to the fact that the geology of several parts of the boundary had to be done before the topographic base-maps of the International Commission were available, it has been found advisable to map parts of the belt which lie entirely in Canada. In such cases I either made a rough sketch map or enlarged for field work the reconnaissance contour maps issued by the Geological Survey Department. The consequence is that the geological map as actually completed is not always symmetrical with respect to the international boundary. From Point Roberts to about the longitude of Sumas lake the geological map will coincide with the Commission topographic map. From Sumas lake to the Skagit river the minimum width of the belt mapped is five miles and the belt lies wholly on the Canadian side. From the Skagit to the Similkameen river the belt is again symmetrical with respect to the boundary line. From the Similkameen to Port Hill the geologically mapped belt is limited on the south by the line; the minimum width is here five miles, but from Christina lake to Port Hill, a distance of about eighty miles, the minimum width is ten miles. From Port Hill to the summit of the Rocky Mountains the Commission topographic map was employed. From that summit to Waterton lake, a distance of fifteen miles, no geological map was made, but a structure section was run to the lake and thus to edge of Great Plains. The total length of the belt mapped is 410 miles; its area, about 2,700 square miles.

I have the honour to be, sir,
Your obedient servant,

REGINALD A. DALY.

PART VI

ROCKY MOUNTAINS PARK OF CANADA

ROCKY MOUNTAINS PARK OF CANADA

REPORT OF THE SUPERINTENDENT OF THE ROCKY MOUNTAINS PARK OF CANADA.

BANFF, ALTA., September 1, 1906.

To the Hon. FRANK OLIVER,
Department of the Interior,
Ottawa.

SIR,—I have the honour to submit for your consideration my report as Superintendent of the Rocky Mountains Park of Canada for the year ending June 30, 1906.

It is a sincere pleasure to me to be able to report that my anticipations of only a few years ago have been already more than realized. The National Park has already developed beyond all reasonable expectations, and from present indications it is difficult to limit its usefulness not only as a unique pleasure resort for the people of the Dominion as well as for visitors from almost every quarter of the habitable world but also as a health resort of the highest and most beneficial character.

Nowhere on the continent of America is there to be found so attractive a beauty spot as the Rocky Mountains Park of Canada. Its magnificent scenery is absolutely unrivalled; the air is clear and invigorating and everything that can be done with the means at the disposal of your department is being done to permit tourists and others to enjoy with the least possible discomfort the many and varied beauties with which the park abounds. It is also pleasing to be able to report that the more recent discoveries are, if anything, more magnificent and more diversified than those of earlier date. The scenery in some portions of the Yoho Valley district baffles description. Tourists who have penetrated from Laggan northwards are unanimously enthusiastic in their praise of the magnificent scenery to be found between the main line of the Canadian Pacific Railway and the Saskatchewan river. In this connection, I would respectfully suggest that the northern limit of the park, in the province of Alberta at least, should be increased from its present boundary, the northern limit of township 34, to the Saskatchewan river which is to-day the natural, though not the official, northern limit in this province. As you are already aware, the present northern boundary is altogether theoretical, the country not having as yet been surveyed, and for the preservation of game as well as for other obvious reasons, the Saskatchewan river would form an ideal and easily recognizable boundary. The country to be included, should my suggestion meet with your approval, is the natural complement of Canada's great playground, and should prove easy of access in view of the proposed construction of railroads through the mountain passes and Northern Alberta to the Pacific coast. The following graphic description of the country adjoining the southern bank of the Saskatchewan river and the district known as the Kootenay Plains, both of which are at present outside of the park limits, is well worthy of perusal, more especially as it is from the pen of Mrs. Schaffer, of Philadelphia, Pa., a lady who, from long acquaintance with the mountains and thorough knowledge of her subject, is eminently well qualified to speak :—

'A recent visit to the Saskatchewan river and Kootenay Plains district, covering a period of three weeks, furnishes ample proof of the desirability of including those sections of the country within the limits of the National Park.

'Our party left Laggan on July 24, heading almost directly north and following the course of the Pipestone river. The Pipestone and the adjoining valleys are in themselves some of the most picturesque features of the trip. Having its birth in the snows of the Pipestone Pass thirty miles from Laggan and 8,400 feet above the sea level, the Pipestone winds along between parallel ranges of comparatively low moun-

tains. These mountains, presumably of limestone, have a uniform dip towards to west or southwest. The summit of the pass is a sight to be long remembered. One follows the course of the Si Fleur river for miles from Laggan away in the south, winding like a silver thread through the green meadows and still greener forests until it becomes lost in the medley of mountains around the Saskatchewan.

'Here the botanist will find a profusion of the rarest alpine plants, and it may be safely said that nowhere through the entire country will the botanist find himself more pleasantly at home.

'The Kootenay Plains are marvels of beauty. A magnificent open grassy valley surrounded by low hills 7,000 or 8,000 feet high and watered by the winding Saskatchewan, it is an ideal resting place for the nature lover or as a temporary refuge from the increasing civilization of this vast country. The Indians have named this section Ka Soona Finda or the Winding Valley, from the soft wind which blows constantly from the north. This chinook wind sweeps away the winter snows and keeps the whole valley delightfully green throughout the entire year. During the summer season the melting snows from the higher mountains which surround it, make the river almost impassable to the tourist. The best trail is on the north side of the river, but owing to the high water the south trail had to be resorted to. This is a more or less dangerous route as the banks of the river are badly undermined and one needs to keep a sharp watch on one's pony, which, although usually a clever trailer, sometimes makes faulty calculation as to the stability of rotten banks.

'Twenty-five miles carries one to the junction of Bear creek and the Saskatchewan river, under the shadow of Mount Wilson. Here is the heart of a magnificent panorama of the higher and less known mountains. Murchison, Pyramid, Sarbach, Survey, Forbes, Saskatchewan and the Freshfield range form a group well worth several days' travel to reach. Turning now towards the south and following Bear creek, the mountains are seen here and there gleaming from among the rich pine forest. The Wild Fowl lakes are among the first to attract the eye in the long series of water stretches. The first of these will promptly appeal to the artistic eye, and the countless ducks fully justify the title. The second, half a mile distant, is almost if not quite as beautiful as its sister. Peyto lake, probably the most dramatic and effective of all the lakes in the Bow region, lies on the north exposure of the Divide. This is a sight which no tourist should fail to see. It lies like a great emerald set in rugged rocks. At its upper end a superb glacier feeds its green waters which eventually merge into Bear creek. One mile further to the south one climbs the last gentle slope and stands on the summit of the Bow Pass.

'Here the well known river which flows through Alberta past Banff and Calgary to the Saskatchewan first sees the light of day. Two beautiful springs of crystal clearness bubble from among the green meadows and start in joyous chatter on their journey south. Even if one goes no further than Bow Summit one feels glad to have seen the vision of beauty which here greets the eye.

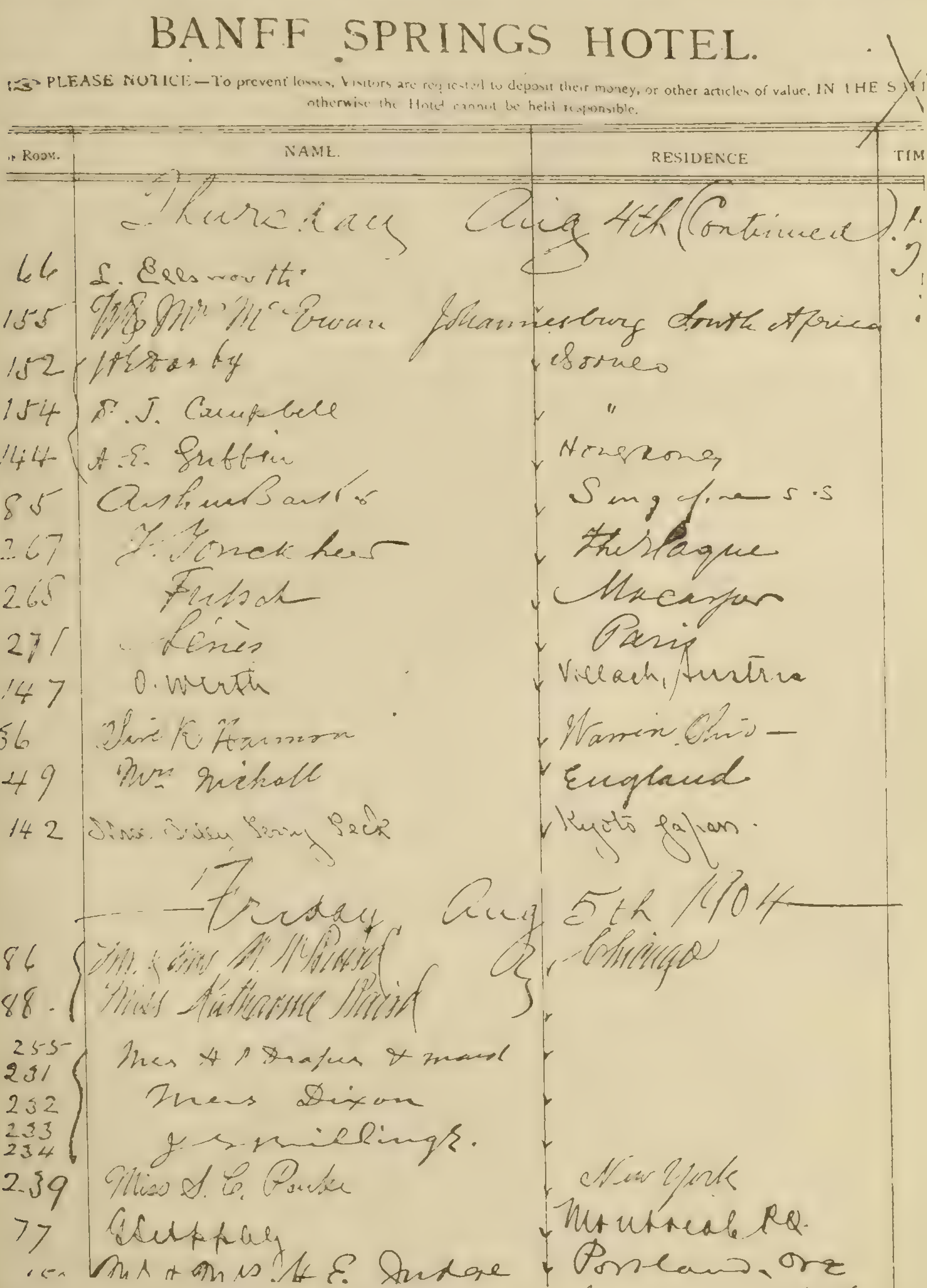
'The Bow lake and Glacier appear two miles further down the valley. One takes a novel trail to skirt the lake, not other than the water of the lake itself. The wise little horses much prefer the pebbly lake bottom to the soft and treacherous muskeg of the shore.

'Lake Hector is the last of this superb group, and we say farewell as we follow the still magnificent mountains and the constantly widening Bow. The last two days of travel to Laggan are but a poor ending to 150 miles of unsurpassable scenery. Twelve miles of muskeg with constant fear of being engulphed, weary horses and miles of fallen timber are the chief characteristics. But it is all worth many times the trouble and inconveniences to be endured which are small enough in comparison with the stupendous magnificence of a district whose beauties will appeal to every lover of nature's treasures.'

I think it unnecessary to add anything to the extract quoted above except to again impress upon you the desirability of including this magnificent district within the con-

fines of the National Park by extending the northern boundary to the Saskatchewan river.

The popularity of the National Park as a tourist resort may best be gathered from the photographic reproduction appended of a page from the register at the Banff Springs Hotel. This is a most interesting contribution to the literature of the park,



BANFF SPRINGS HOTEL.

PLEASE NOTICE—To prevent losses, Visitors are requested to deposit their money, or other articles of value, IN THE S[...] otherwise the Hotel cannot be held responsible.

Room.	NAME.	RESIDENCE	TIM
	Thursday Aug 4th (Continued)		
66	L. Ellsworth		
155	Mr & Mrs McEwan	Johannesburg South Africa	
152	[illegible]	Borneo	
154	F. J. Campbell	"	
144	A. E. [illegible]	Hongkong	
85	[illegible]	Singapore S.S	
267	[illegible]	The Hague	
265	[illegible]	Macassar	
271	[illegible]	Paris	
147	O. Werth	Villach, Austria	
56	[illegible] K Harmon	Warren Ohio	
49	Wm Nicholl	England	
142	Mrs. [illegible] Peck	Kyoto Japan	
	Friday Aug 5th 1904		
86	Mr & Mrs [illegible]	Chicago	
88	Miss Katharine [illegible]		
255 231	Mrs H P Draper & maid		
232	Mrs Dixon		
233 234	J. G. [illegible]		
239	Miss S. C. Parke	New York	
77	[illegible]	Montreal P.Q.	
[illegible]	Mr & Mrs H. E. [illegible]	Portland, Ore	

showing as it does the truly cosmopolitan character of our visitors, and inferentially the fact that the National Park has become known throughout the civilized world. On

a single page are to be found the names of visitors from such distant points as Johannesburg, Borneo, Hong Kong, Paris, Austria, Ohio, England and Japan. What more need be said ?

As will be seen from a comparison of the figures for the year ending June 30, 1906, with those for the preceding year, the number of visitors at the Banff Springs Hotel has almost doubled, while the Sanitarium and other hotels at Banff show a very large increase. As a consequence the revenue of the park has increased by leaps and bounds. The subject is dealt with in detail in another part of my report but I should like to point out here the significant facts that while in July, 1903, our revenue from baths amounted to $263.50, for the same month this year it has reached the eloquent sum of $1,429.50. Similar evidence of increased revenue will be found in the comparison of the amounts received by way of rent. For the year ending June 30, 1903, the revenue from this source amounted to $2,214; for the year ending June 30, 1906, the revenue from rents amounted to $4,055. In other words, the revenue from rents has almost doubled in three years. A comparison of the figures appended hereto with those of former years will show that the revenue from other sources has also largely increased within the same period.

The establishment of the Alpine Club of Canada has already done a great deal to make the National Park attractive to lovers of mountain climbing. This club, which was organized at Winnipeg in March last year under excellent auspices, held its first summer camp at the summit of the Yoho Pass from July 9 to July 16. Over 100 members attended, and the proceedings were entirely successful. The situation was admirably chosen, only twelve miles from the village of Field, and at the same time in the heart of the mountains. The weather was perfect throughout, and Edouard and Gottfried Feuz, the Swiss guides in attendance, did their work most satisfactorily. Eight of the higher mountain peaks were successfully surmounted, Collie, the President, the Vice-President, Marpole, Michael's Peak, Wapta, Burgess and Field.

Forty-four graduating members, of whom fifteen were ladies, duly qualified for active membership by climbing peaks at least 10,000 feet above the sea level. For the official climb the peak known as the Vice-President was selected. This is by no means an easy climb, involving nearly all the various phases of mountaineering. The ascent occupies from seven to eight hours. Visits were also made to points of interest in the vicinity. One of the most pleasant of these was a two-day trip around the Yoho valley, going by the lower trail, stopping the night at the Laughing Falls and returning by the upper trail after a visit to the Yoho Glacier and Twin Falls. The parties each consisted of about twenty persons and all seemed to be delighted beyond expression.

As a consequence of the phenomenal success attending the first camp, the location of the next camp has already been decided upon, and the club has arranged to assemble next year at Paradise valley in the province of Alberta, when it is hoped that the membership will be largely increased.

I may add that the club, under the able presidency of Mr. A. O. Wheeler, F.R.G.S., will during the coming winter issue its first Year-book, which should be of immense assistance in making known to the world some of the wonders of our great Dominion. The Alpine Club has already become a national institution whose importance to the country has, I am pleased to say, been already recognized by your department.

Another matter to which I respectfully desire to draw your attention is the necessity for some more suitable and permanent provisions for the caged animals in the park. These animals, as you are already aware, are now maintained in temporary structures in the Buffalo park, about two miles from the village, and are subject to all the inconveniences naturally arising from the absence of proper sanitary and other necessary equipment. The village of Banff is now provided with an adequate waterworks and sewer system, and I would respectfully suggest that an appropriation be made without delay for the purpose of establishing in the grounds surrounding the museum building a properly equipped zoological garden, where permanent provision might be made for the keeping of our caged animals. Cages constructed of cement and iron in such a

way as to allow their being kept in proper sanitary condition would be not only much more healthful for the animals themselves but much more convenient for visitors to the museum. As will be seen from the details given hereunder we have now in captivity sheep, goats, antelopes, mountain lions, bears, wolves, foxes, &c., which suitably distributed in a convenient place should be most attractive. I am strongly of opinion that the outlay which I have suggested would be well justified by the results and that in a few years the zoological gardens should become one of the leading attractions for visitors to this portion of the National Park. I may add, in this connection, that the birds at present in captivity close to the museum buildings are visited during the season by thousands of persons, who are delighted even with the few specimens on exhibition. We have adjoining the museum about four acres of suitable grounds. These can with very little expense be cleared of underbrush and made into a pleasant and cool resting place for summer visitors. The advantages of the sewerage and waterworks systems in connection with the establishment of the zoological garden are too obvious to require further comment and the central location of the grounds would make the garden most easy of access. I sincerely hope you may be able to see your way to carry cut this suggestion which I think will, in a great measure, solve some of the difficulties under which we labour.

The roads and bridges throughout the park have during the past year been maintained in good repair. In all about eight miles of new road have been constructed since the date of my last report. The two bridges over the Kicking Horse river, mentioned in my report last year, were completed during the past winter and have been in use since the beginning of the present season. These bridges, as you are already aware, are on the main carriage road leading to the Yoho valley, and their usefulness cannot be really proved until the roadway is constructed to its termination.

The wooden bridge over the Kicking Horse at Leanchoil has been raised beyond the reach of high water, and new abutments and trussing have been put in. This bridge is on the road from Leanchoil, on the line of the Canadian Pacific Railway to Wapta Falls and the Ice River valley, where about nine miles of good driving road had been already built by the government of British Columbia before this district was included in the park limits. About nine miles of equally good road has been built by me under your directions from Field to Ottertail, and I now propose, with your approval, to connect Ottertail and Leanchoil by the construction of nine miles more of roadway so as to have a continuous driving road all the way from Field to the Ice River valley, a distance of about thirty miles and through a district which has been described by Mr. Edward Whymper, the famous mountain climber, as 'The beauty spot of the Rockies.'

A bridle trail three miles in length from Leanchoil to the Hoodoos has also been constructed since the date of my last report and five new bridges have been built on the bridge trail already existing between Leanchoil and Wapta Falls. These trails have been needed for a considerable time for the purpose of rendering accessible two points of very great interest. The Hoodoos here are undoubtedly the finest in the mountains and are well worth a visit. They consist of natural columns of cemented gravel standing straight up to a distance of in some cases a hundred feet. The Wapta Falls, which have to some extent been already described in my various reports, are truly magnificent and have been much appreciated during the present season by a large number of visitors. The falls are situated at the junction of the Kicking Horse and Beaver Mouth rivers, the former suffering a sheer drop of about 75 feet, and forming a magnificent waterfall owing to its width which is about 200 feet.

In the village of Field, the streets have been thoroughly cleared and graded and as a consequence the appearance of the town has been much improved. The Emerald lake and Ottertail roads have been carefully looked after, and the damage caused by snow and mud slides as well as by the ever-recurring washouts has been repaired. Work on the carriage road to the Yoho valley is well under way, about seven miles in all having been completed up to the present. This enables the tourist even now to cross the Yoho river near its mouth so as to get a glimpse of the wonders which will be made accessible as soon as the road has been constructed into the valley itself.

A handsome office building for my assistant has been erected at Field. The building, which is of the bungalow style which has become so popular in the park, harmonizes gracefully with its surroundings and its interior is finished in the handsome woods in which the district abounds.

It will be necessary at an early date to replace the present temporary bridge over the Kicking Horse river, at Field, by a structure of a more permanent character, as it is the only artery connecting the village with Emerald lake and the Yoho Valley district. The hotel register at the Mount Stephen House shows about 4,000 visitors at Field during the past year, about 90 per cent of whom would undoubtedly have visited Emerald lake as well. It is estimated that about 1,000 tourists also visited the Yoho valley, even under the present crude conditions. It is therefore evident that, in view of the large and constantly increasing traffic, a permanent bridge is an almost absolute necessity.

In that portion of the park lying east of the village of Banff a good deal of useful and necessary work has been and is now being done. As I stated in my report of last year a good driving road is under construction by the government of the province of Alberta, between the City of Calgary and the eastern limit of the National Park. The work of grading the western end of this road is now being proceeded with, and I have had a number of men employed in grading and otherwise improving the road between Canmore and the eastern limit already mentioned ; as a result, although the road from Calgary to Banff is not as yet in at all as good a condition as I should wish, it has been extensively used by residents of Calgary and the surrounding district, who have by this means been enabled to bring their horses and carriages to Banff during their summer stay, and are therefore enabled to provide themselves and their families with a very necessary and inexpensive mode of locomotion. I may add that this road runs through the new but thriving town of Exshaw mentioned in another portion of this report.

In the village of Canmore one and a half miles of roadway connecting the coal mines with the railway station have been constructed and graded.

I have found it necessary to make arrangements for the replanking of the traffic bridge across the Bow river at the village of Banff. This bridge, which is the only connecting link between the north and south sides of the river, carries a very great deal of the traffic, and the present flooring, which was put in about ten years ago, has survived its usefulness.

The Mountain Park reserve, at Glacier, which was instituted by order in council, in November, 1903, is, as you are aware, outside the limits of the Rocky Mountains Park and Yoho extension. It comprises a territory of about 700 square miles and includes among other things the famous Deutschman caves and the great Glacier of the Rockies, and some of the highest and most magnificent peaks to be found in the Selkirk range, including Mounts Sir Donald (10,800), Fox (10,572), Bonney (10,205), Kilpatrick (10,636), Augustine (10,762), and Cyprian (10,712). Glacier House on the Canadian Pacific Railway line is the centre of this magnificent district and a favourite resting place for tourists. It is the nearest point for those wishing to visit the Glacier and the Deutschman caves, which only need to become known to make them attractive to large numbers of visitors.

During the spring season of the present year I constructed a permanent bridle trail from Ross Peak station to the Deutschman caves, a distance of four miles. This trail with its numerous 'switchbacks' or corkscrew trails affords a charming ride and the scenery from the different points along the road baffles all description. Already, since the construction of this trail, an average of about 50 persons per week have visited the caves. A short distance from the railway I built a log cabin 16 x 18 for the convenience of tourists alighting from the train at Ross Peak, where there are no other buildings of any kind; a similar cabin 18 x 40 has also been erected near the entrance of the caves, and small buildings for storing tools, &c. These cabins are of rustic design, being of split cedar on heavy log frames. In this connection I may say that in the construction of all necessary buildings, I have endeavoured as far as possi-

ble to carry out the rustic design, which is by far the most suitable as well as the prettiest for all buildings in the park. These cabins have been furnished with camp-stoves, cooking utensils and sleeping bunks, so that tourists as well as our caretakers may make themselves as comfortable as possible under the circumstances. The climatic conditions at the summit of Cougar mountain, where the caves are situated, are such as to render some place of refuge necessary for belated travellers, many of whom have already expressed their gratitude for the provision made for their comfort.

In the Deutschman caves, the entrance to that described on the map already sent you as No. 1 has been considerably enlarged.

In the auditorium, one of the vast chambers in the cave, I built a bridge across that portion of Cougar creek which runs through it, to avoid crossing tourists on the temporary raft, which was a constant source of danger. A pathway has been blasted out of the solid rock in this cave to a length of over 200 feet. This, however, is merely the commencement of the work necessary to be done in the caves, which, as I have already reported, are of enormous area and have as yet been explored only for the extent of about a mile.

The caretaker has done a good deal of exploration work himself during the past season, when not occupied in conducting tourists. Altogether it may safely be predicted that the Deutschman caves will in the very near future attract thousands of visitors, who will be amply repaid for the inconvenience accompanying the trip by the wonders of nature which they will be enabled to see.

At Laggan, work has been continued on the carriage road from Lake Louise to the valley of the Ten Peaks. This road is now in use for a distance of about eight miles. I hope to have the remaining four miles completed before winter, so as to enable tourists to visit the famous Moraine lake in the valley. This is one of the most beautiful of the many beautiful spots to be found in the park, and I am informed on good authority that as soon as the road is completed, a handsome chalet, similar to those already built at Lake Louise and Emerald lake, will be erected by the Canadian Pacific Railway Company. When that has been done the latter places must look to their laurels, as competent authorities claim that the beauties of Moraine lake are more accentuated than those to be met at any other point.

The road from Laggan station to the chalet at Lake Louise is now being gravelled and finished. I have experienced no trouble whatever from washouts since the construction of this road, which I am informed may be utilized for an electric tramway in the near future, subject of course to your approval. No formal application for permission has, however, been made as yet, although the matter has been mentioned to me unofficially.

THE VILLAGE OF BANFF.

The beautiful village of Banff, which has been facetiously described as the 'Capital' of the National Park, continues to improve in every desirable direction. The popularity of Banff as a summer home is best evinced by the fact that there are at present no less than 525 lots under lease, producing an annual revenue of over $4,000. Of these nearly one-half have been taken up within the past year and I am daily in receipt of applications for leases of the lots still remaining. I am pleased to report that many of the lessees have erected handsome buildings altogether in harmony with the surroundings, and Banff has to-day many rustic homes which for beauty and comfort it would be difficult to rival. In the business portion of the village some buildings have recently been erected which form in themselves a pleasant addition to the many existing attractions. Amongst these is the building now erected for the Imperial Bank of Canada, which in tastefulness of design and prettiness of appearance stands out prominently. Plans are also being prepared for the erection of barracks for the local detachment of the Royal Northwest Mounted Police, and it is to be hoped that the general idea of rustic design, which I strongly favour, will be carried out in the construction of this building also.

The contract let last year to Messrs. Breckenridge & Lund for the construction of a waterworks and sewerage system is now almost completed, and we are eagerly looking forward to the day which is already close at hand when the residents of the village will be provided with modern sanitary appliances as well as with an abundant supply of excellent water, which will be found invaluable for the purpose among others of beautifying the streets and lawns throughout the village. Our electric light system has proved most satisfactory, more especially in regard to street lighting. We have now thirteen incandescant arc lights, each of 1,200 candle power, placed where most necessary throughout the village streets, and several others will be needed in the future owing to the opening up of new streets and the erection of buildings in the outlying districts. The money expended in this direction is being well spent. The bright light enhances the beauty of the village to incoming travellers, many of whom expect to find themselves in a primitive and unprogressive village, rather than in a beautiful, well-lighted and well-appointed little town, having every characteristic of genuine prosperity and comfort.

Owing to the recent large increase in the number of lots applied for I have found it necessary to clear and grade over two miles of new streets, among these being those shown on the townsite plan as Otter, Cariboo, Wolf and Muskrat streets. The clearing and grading of these streets is a somewhat tedious operation, meaning nothing less than cutting through the virgin forest, felling growing timber, clearing, grubbing out roots, and ploughing the soil so as to bring the streets to a proper grade. About four miles of the main road from the village to Lake Minnewanka has been freshly gravelled and is now in excellent condition. This road requires no little attention as it carries the heavy traffic to Bankhead as well as to Lake Minnewanka. A good deal of work has been done on the road, on the south side of the Spray river, since the date of my last report. Owing to the heavy character of the work, I have been able to complete only one mile in addition to five miles already built. Some unforeseen but necessary work which had to be done in other places prevented me from leaving my workmen on this work for any very great length of time, but I hope by next year to have this road fully completed as far at least as the Canyon or Spray Falls, a distance of about seven miles from the village.

All the roads in the vicinity of the village are being kept up to their usual standard, repairs being made without delay whenever necessary.

MUSEUM BUILDINGS AND GROUNDS.

As will be seen from the report of the curator of the museum (which is appended hereto), over 9,000 visitors registered at the museum building during the past year, besides many others who visited the building but failed to register their names.

Additions are being made from time to time as opportunity offers, to the various collections of specimens on exhibition, and the greater number of visitors seem deeply interested in the different exhibits. The reading and writing rooms are also well patronised, the latter being a great convenience to passing tourists.

I have already pointed out the desirability of clearing the four acres adjoining the museum building, to be used as a zoological garden.

HOTEL ACCOMMODATION.

The ever-increasing number of visitors to the National Park is still a puzzle to the hotel managers at the different points of interest. In Banff itself, Banff Springs Hotel, although now of enormous proportions, is entirely inadequate to the number of its patrons, and the Canadian Pacific Railway Company finds itself again compelled for the third time to make another large addition to its already magnificent building. The Sanitarium has recently been more than trebled in capacity but has again to find more room for its patrons. In the village all the hotels, the King Edward, the Alberta, and

the Park have been more than doubled in capacity, yet it is not an infrequent thing to find numbers of visitors wandering around in search of accommodation, while thousands have been warned against stopping over owing to the lack of room everywhere.

At Laggan, the Canadian Pacific Railway Company has found it necessary to more than double the capacity of the Chalet, which has now been transformed into a palatial hotel, gloriously situated in the centre of one of the most attractive spots to be found in the park. No less than 5,454 people were accommodated at this point during the past year, nearly all of whom were obliged to reserve rooms some time in advance. From present indications the number of visitors to Lake Louise for the present year will be at least double the number given above.

Nearly 4,000 visitors chose the Mount Stephen House at Field as their headquarters, for the purpose of spending a few days at Emerald lake. The accommodation for visitors at both places is excellent but entirely inadequate.

At Glacier House, which is the centre of the Glacier Park, nearly 5,000 were accommodated, which is a tribute to the increasing popularity of this recent addition to the attractions of the mountains. Many people were induced to visit this district owing to the propinquity of the Great Glacier and the Deutschman caves which have already been described.

CAVE AND BASIN AND UPPER HOT SPRINGS.

At the Cave and Basin the increase in the number of bathers has exceeded all reasonable expectations. As already reported, the additional dressing rooms were added in 1904. In 1905 eight more rooms were added and during the past year I added six more rooms, making in all 32 rooms now in use. This accommodation during the past season has proved altogether inadequate, intending bathers being compelled to wait sometimes for hours to secure a dressing room for themselves. Owing to the limited area of the pools the erection of additional dressing rooms would be of doubtful advantage. The question of increasing bathing facilities is one that will have to be carefully gone into, as it will probably involve considerable expense. At the present time the most obvious solution of the difficulty is the erection of another large bath-house at the middle spring, which should to some extent relieve the congestion at present existing at the Cave and Basin. The register at this place for the year ending June 30, 1906, shows 9,566 visitors. For the month of July last past, about 4,000 bathers used the Basin alone. These figures will show the absolute need of increased bathing facilities. I have found it necessary to employ additional temporary help for the laundress in charge of bathing necessaries, during the months of July and August. The revenue from this source has more than trebled within the last three years. Every bather is supplied with a bathing costume and fresh towels at a charge of 25 cents (bath included). This, as you will have seen, is one of the most popular of our attractions.

The popularity of the baths at the Upper Hot Springs, although not quite two years in operation, has caused similar difficulties to those experienced at the Cave and Basin. Indeed, here the difficulty seems to be almost insurmountable. The pool, which is patronised almost entirely by invalids who come from all parts of the world, has become altogether too small for the number of those using it. I originally had eight dressing rooms built, which I thought would have been ample for some time to come. I very soon found it necessary to add eight more, and this year I shall have to add eight more, making in all 24 rooms. There is no advantage in adding further accommodation, for the reason that the pool is only 24 x 48 feet in all, and our private baths are only ten in number. The marvellous cures effected here have become known in distant lands, and the result is that invalids from every conceivable place come here for treatment, which in almost every case results in a cure. The problem now before your department is to find means to meet this ever-growing demand. In my opinion it will be necessary with the least possible delay to erect a modern hydropathic establishment

with a resident physician in charge. The revenue to be derived from such an establishment will undoubtedly in a very short time repay all the expense of construction and maintenance besides leaving a handsome surplus. Moreover, the enormous benefit which the government can in this way confer on suffering humanity would entitle the administration to the sincere gratitude of the people of Canada and other countries as well. It is impossible for one who is not on the spot to realize the curative properties of the waters at the Upper Hot Springs. In rheumatism and kindred ailments, some marvellous cures have already been effected, with the result, as stated above, that it has become almost impossible to cope with the increased patronage, or to give relief to many who urgently need it. I trust that you will give this matter your earliest attention.

I reproduce for ready reference the analysis made by A. McGill, government analyst, of the water from this spring :

	Millegrammes per litre.	Grains per gallon.
Chlorine (in chloride)	6·0	0·42
Sulphuric acid (SO_3)	550·0	38·50
Silica (SiO_2)	33·0	2·31
Lime (CaO)	355·0	24·85
Magnesia (MgO)	69·5	4·87
Alkalies (expressed in terms of Na_2O)	8·9	0·62
Lithium	A decided trace.	Trace.
Sulphuretted hydrogen (H_2S)	4·3	0·30
Temperature of water	115·5° F.	
Albuminoid nitrogen	None.	None.

THE AVIARY.

The golden eagle, a splendid specimen, is being kept at the Buffalo paddock, owing to lack of proper accommodation in the Aviary. The great horned owl and a large fish hawk, also fine specimens, are also confined at the paddock for similar reasons.

The birds in the Aviary show a fairly satisfactory increase, without any loss whatever, but I do not as yet feel justified in setting any of them at liberty. Our different varieties of pheasants are seen daily by large numbers of visitors. Since my last report I have added a large wire cage 20 x 50, containing specimens of Canadian wild geese, wild ducks and mud hens. The cage is built over a natural pond in the museum grounds and the birds up to the present seem to be in a healthy condition. I hope when opportunity offers to secure further specimens of native water fowl to add to our present little collection.

THE FAUNA OF THE PARK.

The animal paddock, in which are kept our herd of buffalo and other big game as well as the caged animals, has during the past year fully maintained its hold on popular favour, the number of visitors passing through the gates being 12,090 as against 8,000 for the year preceding. In addition a large number of pedestrians visit the paddock and inspect the animals from the outside fence. Of these no record is kept.

During the past year the buffalo have increased by ten head, making our herd in all 61 head. All the animals are healthy and in a thriving condition. The elk, moose, mule, deer, Persian sheep, goats, and indeed, all the animals in our collection have shown satisfactory increase and are doing well. Since the date of my last report a fine specimen of the male antelope has been added. As already pointed out, I hope to secure your approval to the transfer of the caged animals to the museum grounds, where they can receive better care and attention and be placed in the less irksome confinement.

The animals now in captivity in the park under my care are as follows :—

Buffalo	61
Elk	8
Moose	12
Mule deer	16
Persian sheep	4
Angora goats	5
Antelope	1
Mountain lion	2
Bear	2
Wolves	4
Coyotes	
Foxes	5
Badgers	2

THE FLORA OF THE PARK.

The past year has been remarkable for the large numbers of botanical students who have visited the park, attracted no doubt by the glowing reports of earlier visitors. The botanical specimens on exhibition at Lake Louise, Field and Glacier House have also attracted visitors, who find here an unsurpassable field for botanical research. Even to the non-botanical mind, the wild flowers of the National Park are a revelation.

'Here are pink garlics, harebells swaying in wild waywardness, veronicas looking up with their wide-open blue eyes, heathers red, rose and white, amethyst asters, and sweet scented orchid, all mingling their perfume with the shining green leaves and waxen petal of the rhododendrons and great snowy chalices of the globe flowers.'

It is difficult to describe the glorious beauty of an alpine meadow. Here indeed man meets nature face to face and finds that it is good.

The recent publication of Mrs. Henshaw's excellent work on the mountain wild flowers of Canada will do much to provide lovers of nature who visit the park with a popular and at the same time scientifically accurate guide to the striking wild flowers which they are most likely to meet in the course of their rambles, besides affording to the ordinary tourist a means of identifying some at least of the many wild flowers whose beauties obtrude themselves on his attention at every point.

THE BANKHEAD MINES.

At the Pacific Coal Company's mines, at Bankhead, which have been in steady operation during the past year, a large amount of development work has been done and several new seams of marketable coal have been opened up. Up to date nine seams have been encountered, and of these, eight vary in thickness from 4 feet 6 inches to 10 feet. Seven seams have been extensively developed, but at the present time, the output from three of these is sufficient to supply the demands for the product of the mines, which is now on sale from Winnipeg to Vancouver, and from Edmonton on the north, to Spokane, Washington, and Great Falls, Montana, on the south.

The breaker, which was in course of construction during the summer of 1905, was completed and in operation at the beginning of November. In this building the coal as it comes from the mine is cleaned and sized, and from it passes to the various bins underneath. From these bins it is drawn off as required, and loaded into railroad cars by means of a carrying belt and Victor Box Car Loader. The breaker is designed for an output of 2,000 tons in a day of ten hours. It has at present a capacity of only half that amount, but it is the intention ultimately to instal the remainder of the machinery, when the plant will be equal to any demand which may be made upon it.

Compressed air locomotives, of which there are now five in operation, are used for underground haulage, for handling the coal cars in the yard and the cars for dumping

the dirt and refuse. These locomotives are equipped with storage tanks, designed to carry air at a pressure of 800 lbs. per square inch, which is reduced, by means of reducing valves, to a working pressure of 140 lbs. per square inch.

Surface improvements during the year include the building of 25 five-room cottages for employees, and the erection of a school-house, which during the past session has had an average attendance of 44 scholars.

It is the intention of the coal company to manufacture briquettes from the coal dust, which is unavoidably produced in the preparation of the various sizes of cleaned coal; and at the present time, there is under construction a briquetting plant, which will have an ultimate capacity of 400 tons per day of 24 hours.

For the present, and until a market has been worked up for this class of fuel, only a single unit plant will be installed, but all the buildings are designed for the purpose of a two-unit plant. These buildings comprise melting-house, where the binding material is melted, before being mixed with the coal dust, a briquetting house, in which are mixers, to thoroughly mix the coal dust and binder, and a press, which moulds and compresses these materials. From the briquetting house, the hot briquettes pass to the cooling-house, where on a travelling cooling table they are cooled and thus hardened before passing to the bins, from which they are loaded into railroad cars.

These briquettes have been thoroughly tested, in locomotives, and steam boilers, furnaces, stoves, ranges and grates, and have been found to be an excellent fuel for all purposes, and when the public has had an opportunity of judging of the quality of this fuel, there is little doubt but that it will come into general household use. This will mean the steady employment of a considerable number of additional hands at Bankhead, and increased prosperity for that growing town.

THE EXSHAW CEMENT WORKS.

The industrial assets of the park have been increased since last year by the establishment of a Portland cement mill of large capacity. The enterprise is located at Exshaw, in the province of Alberta. In order to find material for the manufacture of Portland cement, with which to supply a portion of the great demand of the west, a prospecting party under direction of the managers of the Cement Company at Hull, Quebec, was put in the field at Winnipeg in 1903. This party worked west as far as the foot hills and into the mountains before the necessary materials were discovered in sufficient abundance and in close enough proximity to warrant the erection of a large mill. In August, 1904, at a point of the Canadian Pacific Railway, north of Lake des Arcs or Sand lake, about three miles east of the Gap, a large deposit of limestone was found, bearing a high percentage of carbonated lime. Shale containing the necessary proportions of silica and alumina and some iron were discovered close by, and as coal is plentiful in the vicinity, steps were taken to acquire the various parcels of land in which these materials were located. The limestone and cement shale were found to be within the park limits and leases were applied for and granted in 1905. Another tract containing shale situated at Radnor, outside the park limits, as well as a large freehold area of coal lands at Anthracite were purchased outright. In August, 1905, a company was incorporated, called the Western Canada Cement and Coal Company, Limited. The above mentioned properties were taken over by this company and operations were commenced at once.

The total area of the company's property aggregates 1,271 acres all within economical distance of the mill, which is being constructed at the location of the heaviest constituent, the limestone rock.

Beautifully situated on a gentle slope overlooking Lake des Arcs, with a magnificent view in every direction, the new town of Exshaw, the centre of a great manufacturing industry, has arisen out of the valley of the Bow river.

The plant itself is being constructed in a most substantial manner. The foundations for the machinery and mills are of concrete, and the buildings of reinforced con-

crete and cement blocks with heavy concrete arches and piers. The tunnels are of solid concrete two and three hundred feet long. Structural steel trusses and girders, all covered by metal roofing, make the buildings absolutely fireproof. The mill buildings cover an area of about seven acres and the roof area alone is over three acres.

The machinery consists of six 80-foot rotary kilns, seven rotary dryers, 12 Krupp ball mills, 18 tube mills with crushers, shafting, conveyors and electrical apparatus of the best and most modern pattern. The power-house, which consists of three turbines developing 1,000 K.W. each, operated by seven Babcock and Wilcox boilers, will be one of the largest power-houses in Canada. The mill is planned to have a minimum capacity of 1,500 to 1,800 barrels per day with room for extension. The cost when completed will be $1,000,000. About half of that amount has already been expended.

The town is well laid out and contains already twenty or more neat buildings, consisting of dwelling houses, hotel and a general store. Both the town and the mill are supplied with excellent water from a mountain stream, on which is being built by means of a concrete dam, a reservoir of 7,000,000 gallons capacity. Several thousand feet of water mains have been laid already and the mill is provided against fire with twelve hydrants each throwing water at a pressure of 90 lbs. Hydrants are also placed at convenient places throughout the town. At the time of writing, the employees at Exshaw with their wives and families number about 500 people, living, some in cottages and some in tents, until suitable dwelling houses can be provided by the company at a rental equal to a moderate rate of interest on the actual cost. Many of these cottages are now under construction. In addition to the water supply, a telephone system has been installed, and water and sewerage connection made with each house. The houses and mills as well as the streets will be lighted electrically as soon as the power plant has been put in running order.

The erection of these large cement mills within the park will prove an important step in the building up of Western Canada. With an output of half a million barrels of cement a year they will not only circulate a large sum of money in this neighbourhood, but they will provide a most necessary material for the construction of railways and large industrial buildings throughout this country and supply cheaper and better building material for the settler than he is now able to procure.

PRESERVATION OF GAME.

I find no little difficulty in enforcing the laws regarding the preservation of game, within the limits of the park. Game is generally killed only in the more remote districts, and offenders are careful to see that their actions are unobserved, so that there is very great difficulty in securing evidence of unlawful killing other than the possession of game during close season. Again, as I have already pointed out, the boundaries of the park are in some places not by any means clearly defined, and it is therefore obviously difficult in many cases to secure convictions for shooting game within the park limits. In this connection I would strongly recommend the appointment of two permanent guardians who would act as fish guardians and fire wardens as well. One of these should devote his attention to that portion of the park that is within the province of Alberta, while the other should look after the portion located within the province of British Columbia. I have found the engagement of temporary game guardians during a few months in each year to be most unsatisfactory in result. These men, knowing that their position is merely a temporary one, are inclined to wink at breaches of the law rather than incur the enmity of their neighbours. If, however, the appointment were made a permanent one, I have no doubt whatever that game guardians would properly appreciate the responsibility of their position, and would as far as lies in their power see that the law was carried out. The proper protection of game is just as important in the winter season as during the summer months. Trappers have been known to come in on the snow, and shoot and trap large quantities of game, as well as drive herds of big game well out of the park limits to a remote place where they may destroy

them with comparative safety. There is at present a good number of big game in the park, consisting chiefly of moose, elk, deer, bear, sheep, lynx and goat, as well as marten and beaver, besides an unlimited number of game birds. As the park is the natural breeding ground of many varieties of animals it is not at all uncommon to run across a herd during one's wanderings in the mountains. The present is by far the best time to give these animals proper protection so that the different herds may increase naturally, and that the large expense incident to the restocking of the game preserves in the future may be avoided.

Among the offenders against the game laws, the Indians are by far the worst. They invade the National Park at all seasons of the year, and slaughter any animal they run across without regard to age or sex. The greater part of the meat of the animals so killed is dried and packed away for future use. The Indian has been led to believe that he is entitled to slaughter game at any time of the year and wherever he may find it. I would recommend that your department should without delay instruct all Indian agents in the west to notify the Indians in their charge that they are not permitted to shoot any game of any kind at any time in the Rocky Mountains Park, and that any offender against the law in this respect would, if convicted, be subjected to the maximum penalty allowed by law. The adoption of this course would, I think, effectually put a stop to the indiscriminate killing of game within the park limits and more especially around the southern boundary of the Yoho valley extension, which in my opinion should be surveyed without delay so as to leave no possible excuse as to ignorance of the delimitations of the park. I would also recommend that no further mining or timber licenses be granted within the park, for the reason that I have found by experience that the establishment of large camps of men invariably leads to trapping and snaring and in fact to almost every possible breach of the laws for the protection of game.

FISH AND FISH HATCHERY.

The excellent fishing to be had in the park has during the past year attracted large numbers of followers of 'the gentle art.' I must, however, draw your attention to the fact that the big catches which were common in former years are becoming almost unknown, and the irresistible conclusion, more especially with regard to the more accessible lakes and streams, is that these are being rapidly fished out, and that it will be necessary in the near future either to restock many of them or to curtail or even abolish the open season for some time.

As you may be aware, the open season for trout fishing instead of being shortened as in my judgment it should have been has been extended this year in Alberta so as to allow trout to be taken two weeks earlier and two weeks later than heretofore. This, in my opinion, is a very grave error, as far as the Rocky Mountains Park is concerned. Throughout the entire open season hundreds of visitors to the park are to be found on the banks of the more accessible fishing grounds busily engaged in taking fish, without any limit whatever as to the number. I would urgently recommend that the open season in the Rocky Mountains Park should be very much curtailed rather than extended. No person should be allowed to fish without having first obtained a license so to do, and a license fee might reasonably be demanded from non-residents of Canada. A limit should also be placed upon the number of fish to be taken by any one person in any one day. These are among the enactments which, as the result of my experience, I think should be made for the proper regulation of trout fishing in the park. It is my intention at an early date to submit for your consideration a set of proposed regulations which, if you approve, should be added to those now in force, and which would render the National Park independent of the general fishing regulations of the country.

Since the date of my last report the Canadian Pacific Railway Company has brought in no less than three carloads of trout from Lake Nipigon and from the Wisconsin hatchery. These have been placed in the rivers near Banff, at Lake Louise, near Laggan, and at Emerald lake in the Yoho valley.

In order to maintain an adequate supply of trout and other suitable fish for our lakes and streams, I would again urge the establishment of a properly equipped fish hatchery at some one of the many suitable locations to be found within the park. We should then be in a position to supply not only our own requirements but those of the provinces of Alberta and Saskatchewan as well. As already pointed out, there are in the park many lakes and streams apparently suitable for the support of fish which are as yet entirely devoid of either lake or brook trout. The establishment of a fish hatchery would in a short time remedy this state of things, besides making the park still more attractive for fishermen as well as for other visitors desiring to study the various phases of fish life.

PREVENTION OF FOREST FIRES.

Owing to the dryness of the past season serious forest fires broke out at several points in the park, the suppression of which involved a great deal of trouble and expense. A large area of green forest was unfortunately destroyed, although no other damage was done. All the men regularly employed in the park as well as all the outside help available were engaged day and night for a considerable time fighting these fires and preventing them from spreading. Although large tracts of timber were consumed, we succeeded to a very large extent in retarding the progress of the flames.

Our fire guardians, who patrol the railway regularly twice daily, have on many occasions been successful in preventing what would otherwise be disastrous fires caused by sparks from passing trains. At present, even with the greatest vigilance, it is impossible to prevent fires from spreading, and the cost of detecting and suppressing these fires has during the past year been one of my heaviest items of expenditure, for which no provision has been made. I would respectfully suggest that a sum of money be appropriated during the present year to meet contingencies of this kind, as it is hard to say what we may be called on to expend at any time should we meet with a continuance of dry seasons.

REVENUE.

The revenue of the Rocky Mountains Park is now more than double the amount ordinarily required for current expenditure and maintenance.

I have again to acknowledge the liberality of the grants made by parliament for the maintenance and development of the park. I have endeavoured to the utmost of my ability to expend the moneys entrusted to me as economically and judiciously as possible and to ensure the best and most lasting results. The constantly increasing popularity of the park and the prospect of the large additional revenue which is to be derived from different sources would undoubtedly seem to justify the still larger expenditure necessary to keep pace with growing requirements.

I would again draw your attention to the meteorological reports which will be found appended hereto. A perusal of records of temperature to be found therein will indisputably show that the climate of the National Park is exceptionally mild and equable, and that the district is quite as well adapted for a winter resort as it undoubtedly is for a holiday resort in summer. All the hotels in the village are kept open throughout the winter and the clear, bracing mountain air has proved most beneficial to those who have taken up their winter quarters in the National Park. It is gratifying to note that the number of winter visitors is also rapidly increasing.

In conclusion, I desire once again to acknowledge the faithful work done by the employees who have worked under my directions during the past year, as well as the loyal and cordial support given me by the officers and men of the Royal Northwest Mounted Police in my efforts to maintain law and order within my jurisdiction.

I have the honour to be, sir, your obedient servant,

HOWARD DOUGLAS,

Superintendent Rocky Mountains Park of Canada.

VISITORS.

CANADIAN PACIFIC RAILWAY COMPANY'S HOTEL.

Canada	2,345
United States	6,703
England	77
Ireland	21
Japan	27
India	23
Hungary	2
South Africa	6
New Zealand	37
New South Wales	9
Germany	22
Australia	48
China	37
Italy	2
Switzerland	3
Gibraltar	2
Egypt	2
France	7
Portugal	4
Transvaal	4
Jamaica	2
Fiji	4
Belgium	2
Austria	2
Total	9,684

SANITARIUM HOTEL.

Canada	4,496
United States	2,075
England	96
Scotland	21
Australia	59
New Zealand	52
Ireland	11
Germany	10
China	9
Japan	7
India	7
Portugal	2
Switzerland	1
Korea	1
Total	6,847

KING EDWARD HOTEL.

Canada	2,904
United States	880
Scotland	23
England	20
Ireland	3
Japan	4
Italy	4
New Zealand	4
Egypt	2
Alaska	2
West Indies	2
Total	3,848

ALBERTA HOTEL.

Canada	2,267
United States	907
England	19
Scotland	10
Ireland	10
New Zealand	17
France	1
Australia	5
South Africa	2
India	2
Japan	2
China	1
Borneo	1
Sumatra	1
Russia	1
Egypt	3
New South Wales	1
Total	3,250

PARK HOTEL.

Canada	1,200

GRAND VIEW HOTEL.

Canada	1,350
United States	293
England	25
Germany	4
Australia	11
New Zealand	10
Scotland	5
Sweden	2
Holland	1
Ireland	5
Mexico	4
Austria	1
Honolulu	3
Total	1,714

HOT SPRINGS HYDROPATHIC.

Canada	414
United States	171
Scotland	2
England	6
Total	593

SUMMARY.

Canadian Pacific Railway Company's Hotel	9,684
Sanitarium Hotel	6,847
King Edward Hotel	3,848
Alberta Hotel	3,250
Park Hotel	1,200
Grand View Hotel	1,714
Hot Springs Hydropathic	593
Excursions not registered	1,500
Summer visitors residing in cottages and camps	1,500
Total	30,136

LAKE LOUISE CHALET.

Canada	991
United States	4,171
England	143
Scotland	13
Ireland	5
Australia	31
Germany	25
New Zealand	13
New South Wales	12
China	11
Hawaii Islands	6
West Indies	5
South Africa	4
France	4
Italy	4
Japan	4
India	2
East Indies	2
Portugal	2
Wales	1
Tasmania	1
Switzerland	1
South America	1
Philippines	1
Fiji	1
Total	5,454

MOUNT STEPHEN HOUSE, FIELD, B.C.

Canada	1,336
United States	2,353
British Isles	224
Australia	53
Total	3,966

GLACIER HOUSE, GLACIER, B.C.

Canada	1,850
United States	2,850
British Isles	210
England	15
Total	4,925

MUSEUM.

Canada	5,027
United States	3,461
England	355
Scotland	128
Australia	52
New Zealand	39
China	33
Ireland	24
Germany	16
Wales	15
Italy	14
France	14
Japan	11
New South Wales	10
India	8
Hawaiian Islands	7
Queensland	5
British North Borneo	5
Russia	4
Channel Islands	4
Denmark	3
Sweden	3
Austria	3
South Africa	3
Natal	2
Bohemia	2
Norway	1
Siam	1
West Indies	1
Greece	1
Brazil	1
Belgium	1
British Honduras	1
Switzerland	1
Palestine	1
Hungary	1
Total	8,961

CAVE AND BASIN.

Canada	4,439
United States	4,519
England	186
Scotland	161
Ireland	75
Australia	53
New Zealand	36
Queensland	13
New South Wales	9
South Africa	5
India	10
Japan	16
China	15
Fiji Islands	2
Germany	7
Sweden	5
France	4
Russia	2
Holland	4
Switzerland	5
Total	9,566

UPPER HOT SPRINGS.

Canada	8,314
United States	1,465
England	74
Scotland	41
New Zealand	7
Australia	20
India	4
Sweden	11
Total	9,936

MUSEUM.

Well on to 9,000 visitors are shown on the museum report, this would, no doubt, be well over 9,000 if all had registered who visited the museum.

It is hoped that many specimens may be added in every branch of the work. As curator I have used a good deal of my unoccupied time in collecting the different orders of flies.

I am, sir, yours truly,

N. B. SANSON,

Curator.

H. DOUGLAS, Esq.,
Supt. Rocky Mts. Park.

METEOROLOGICAL TABLES.

ROCKY MOUNTAINS PARK.

MAXIMUM and Minimum Temperatures and the General State of the Weather between July 1, 1905, and June 30, 1906.

Date.	Thermometer Readings.				Weather.
	Maximum.		Minimum.		
	6 a.m.	6 p.m.	6 a.m.	6 p.m.	
1905.					
July 1....	63·7	68·1	39·5	40·4	Fair, rain.
" 2....	60·3	69·0	44·8	45·1	Cloudy, thunder.
" 3 ..	59·4	70·6	40·8	42·1	Fair, rain.
" 4 . .	62·9	65·9	40·8	42·0	Cloudy.
" 5 ..	61 5	67·9	46·0	46·8	Fair.
" 6....	65·9	72·9	37·5	38·0	" thunder.
" 7 ..	66·6	62·4	42 7	44·3	" rain.
" 8 ...	61·6	79·3	36·8	37·3	" perfect day.
" 9....	74·9	84·3	44·3	45·5	"
" 10....	79·2	77·8	47·7	47·4	"
" 11....	68·1	59·4	47·2	46·3	Cloudy, rain.
" 12...	57·4	69·3	34·5	35·2	Fair.
" 13....	64·6	74·0	37·9	37·8	Cloudy, rain, triple rainbow, vivid lightning.
" 14....	56·0	59·3	41·8	46·9	Fair.
" 15....	51·5	70·2	41·3	42·0	" lightning.
" 16....	66·6	64·0	47·2	48·6	" rain.
" 17....	59·8	61·9	45·1	46·6	Cloudy, rainbow.
" 18....	56·7	72·4	43·0	43·8	Fair.
" 19....	67·9	79·4	38·1	38·1	"
" 20....	76·0	84·9	42 8	42·1	"
" 21....	79·8	87·4	45·2	46·0	" vivid lightning, thunder
" 22....	76·9	87·2	47 1	47·0	"
" 23....	78 8	88·1	48·3	48·0	"
" 24....	72·6	75·2	49·5	49·2	" rain.
" 25....	59·2	69·7	47·2	48·3	Cloudy, rain, thunder and lightning.
" 26 ...	59·6	63·0	51·7	51·4	" "
" 27....	55·8	65·9	49·2	49 5	"
" 28....	63·9	75·0	45·2	42·0	Fair.
" 29 ...	62·6	68·6	45·2	47·9	"
" 30. .	65·8	77·0	46·0	48·8	"
" 31....	66·8	72·5	47·8	48·4	" rain.
Aug. 1....	65·5	74·9	49 8	49·8	Cloudy.
" 2....	64·4	78·9	45 6	45·2	Fair.
" 3...	71·8	69·0	46·7	47 1	" thunder and lightning, rainbow, rain.
" 4. ..	68·7	77·0	42·9	42·9	"
" 5...	70·9	80·5	39·7	45·1	"
" 6....	74·4	83·6	43·2	43·2	"
" 7....	77·3	81·5	50·2	49·8	"
" 8....	76·6	83·5	43 7	46·2	"
" 9....	78·4	78·6	51·3	52·0	"
" 10....	70·9	70·2	42·8	42·8	" smoke from bush fires.
" 11....	69·6	79·0	41·0	46·5	" " "
" 12....	68·8	79·5	47·3	48·8	" thunder and lightning.
" 13....	70·6	78·2	43·1	44·9	"
" 14...	67·2	67·2	39·2	39·9	"
" 15....	58·8	54·4	39·2	39·2	Cloudy, rain.
" 16....	53·1	57·4	45·7	45·8	"
" 17....	53 7	58·4	43·8	46·2	"
" 18....	54·2	61·3	44·0	48·0	"
" 19....	57·4	65·9	53·0	52·7	Fair.
" 20 ..	56·9	68·0	39 9	40·2	"
" 21....	63·8	71·3	41·7	42·1	"
" 22....	62·8	71·5	30·7	31·0	"
" 23 ...	66·4	71·1	30 4	30·0	"
" 24....	67·9	74·2	31·3	31·3	"

MAXIMUM and Minimum Temperatures, &c.—*Continued.*

Date.	Thermometer Readings. Maximum. 6 a.m.	6 p.m.	Minimum. 6 a.m.	6 p.m.	Weather.
1905.	°		°		
Aug. 25....	70·0	80·3	34·1	34·2	Fair.
" 26....	73·8	67·7	48·4	51·3	" smoke from bush fires.
" 27....	62·3	75·4	33·9	32·9	" " "
" 28....	68·8	61·7	43·3	44·0	" rain.
" 29....	58·7	67·5	33·0	32·8	"
" 30....	63·6	67·0	35·3	37·9	Cloudy, rain.
" 31....	44·2	44·1	38·7	38·7	" "
Sept. 1...	43·0	60·8	36·2	37·0	"
" 2....	58·4	70·3	33·8	34·0	Fair.
" 3....	67·7	74·3	35·3	35·2	" perfect day.
" 4....	69·3	67·5	33·8	33·2	" lightning.
" 5....	64·5	71·4	38·5	38·3	" rain, fine sunset.
" 6...	64·7	59·4	37·8	37·0	"
" 7....	52·7	46·6	40·9	40·2	" rain.
" 8....	44·1	60·9	41·9	42·3	Cloudy "
" 9....	53·5	61·4	43·9	43·7	"
" 10...	56·0	62·8	44·1	43·8	Fair.
" 11...	54·2	55·2	43·4	42·8	"
" 12...	47·7	67·9	39·7	39·5	" geese flying South.
" 13....	64·6	62·6	33·8	33·8	Cloudy.
" 14....	58·7	58·9	43·2	42·7	" rain.
" 15....	48·7	55·3	25·8	25·3	Fair.
" 16....	50·1	54·9	39·5	39·1	Cloudy.
" 17....	47·9	51·6	39·7	39·3	" rain.
" 18....	46·7	53·1	40·4	40·2	"
" 19....	53·2	62·5	46·8	53·1	"
" 20....	57·0	51·7	43·7	45·2	" "
" 21....	50·0	56·4	41·3	41·5	" "
" 22....	50·5	67·6	47·1	47·6	Fair, rain.
" 23....	58·7	55·4	45·2	44·3	"
" 24...	53·9	69·8	34·1	34·4	" "
" 25....	56·7	49·9	39·3	39·7	Cloudy, rain.
" 26....	45·0	49·3	39·9	39·1	" "
" 27....	41·4	48·4	34·2	33·0	"
" 28....	44·4	49·3	33·6	33·3	" "
" 29..	36·9	48·1	30·5	30·0	Fair.
" 30...	42·8	48·2	31·8	32·7	"
Oct. 1....	43·4	45·0	26·7	25·5	"
" 2....	39·7	46·3	35·2	36·0	Cloudy.
" 3....	42·9	51·3	35·9	35·9	" rain.
" 4....	46·7	49·0	35·1	34·7	"
" 5...	41·9	46·2	35·3	35·3	" rain, thunder.
" 6....	41·4	41·2	31·8	31·3	" rain and snow.
" 7...	38·7	36·2	33·4	32·1	"
" 8...	34·6	42·4	30·7	31·7	"
" 9....	33·6	40·6	24·6	25·1	Fair, ice on still water.
" 10...	35·6	47·6	23·7	23·9	"
" 11....	43·0	46·0	34·8	37·2	Cloudy.
" 12....	41·8	41·8	32·2	31·2	" snow.
" 13....	32·8	40·7	20·8	19·2	Fair.
" 14....	35·6	42·3	26·4	24·5	"
" 15....	36·8	36·2	28·8	28·9	Cloudy.
" 16....	30·6	37·7	24·5	26·2	" snow.
" 17....	32·6	16·4	11·7	9·7	" " 2½ inches on ground.
" 18...	9·9	25·1	— 2·1	— 3·3	Fair.
" 19....	21·9	35·2	10·8	13·7	"
" 20....	31·9	38·8	22·2	24·0	" no snow on ground.
" 21....	34·6	40·3	20·2	18·3	"
" 22....	37·5	41·1	32·3	31·5	Cloudy.
" 23....	36·9	43·7	33·5	32·9	"
" 24....	39·5	46·1	35·8	35·2	" rain.
" 25....	42·3	42·3	36·2	34·3	" "

MAXIMUM and Mimimum Temperatures, &c.—*Continued.*

Date.	Thermometer Readings.				Weather.
	Maximum.		Minimum.		
	6 a.m.	6 p.m.	6 a.m.	6 p.m.	
1905.	°	°	°	°	
Oct. 26...	34·4	38·6	20·1	18·9	Fair, skating.
" 27....	33·2	35·6	22·9	21·0	"
" 28 ...	27·3	36·2	13·5	12·6	"
" 29....	31·6	34·1	9·2	8·7	"
" 30....	28·6	41·7	11·3	11·3	"
" 31....	35·3	42·2	20.8	20·7	"
Nov. 1....	37·2	40·3	29·3	32·2	Cloudy.
" 2....	37·7	38·8	23·2	21·8	"
" 3....	39·6	43·0	31·7	34·5	"
" 4....	38·7	42·0	28·4	29·4	Fair.
" 5....	36·6	40·0	22·1	21·8	Cloudy.
" 6....	38·4	46·6	30·4	30·0	Fair.
" 7...	44·0	49·7	31·3	30·7	"
" 8...	41·8	48·8	24·7	22·7	" perfect day.
" 9....	35·8	49·8	25·8	25·2	" "
" 10....	39·7	47·8	26·4	25·8	"
" 11....	40·9	49·1	33·7	34·5	"
" 12....	46·5	51·8	38·8	38·6	"
" 13....	43·4	47·2	28·3	28·3	"
" 14....	46·7	46·9	39·6	44·2	Cloudy.
" 15....	45·7	50·1	43·7	42·9	Fair, rain.
" 16....	48·8	42·9	41·7	34·9	Cloudy.
" 17...	41·7	44·2	29·9	29·2	Fair.
" 18...	43·6	35·7	31·5	32·0	"
" 19....	33·7	35·8	28·3	29·3	Cloudy, snow.
" 20....	33·2	31·1	29·3	24·9	Fair, no snow on ground.
" 21...	25·5	31·7	10·9	11·2	" river frozen over.
" 22....	29·4	34·1	24·4	22·4	"
" 23...	34·1	32·0	30·2	26·0	"
" 24...	33·2	36·6	25·8	31·2	Cloudy.
" 25....	31·6	32·9	25·5	24·0	" snow.
" 26....	24·6	17·5	16·6	1·8	" "
" 27....	1·8	— 2·8	— 7·1	— 8·4	" " first sleighing, but bad.
" 28....	— 8·1	0·3	—10·8	—10·8	Fair, snow.
" 29....	0·0	13·0	—11·0	— 9·9	"
" 30....	12·5	18·3	5·9	3·2	" snow, ice on Bow, about 6 inches.
Dec. 1...	11·8	16·1	— 9·3	— 8·7	"
" 2....	14·5	20·8	— 0·8	9·8	"
" 3....	20·0	28·3	18·6	17·6	"
" 4....	24·6	28·1	13·5	13·9	Cloudy.
" 5....	27·6	34·4	20·6	18·3	Fair, thaw, chinook.
" 6....	36·0	36·6	28·6	30·2	Cloudy, snow, 4½ in. snow on ground.
" 7....	31·6	30·2	11·7	11·0	Fair.
" 8....	25·4	27·8	10·5	10·2	"
" 9....	23·6	37·0	13·2	13·0	" squally wind.
" 10...	38·2	42·2	32·1	36·7	Cloudy, " "
" 11....	39·8	32·3	30·7	24·8	"
" 12....	25·0	34·3	18·8	19·7	Fair.
" 13....	31·6	29·3	25·3	23·7	"
" 14....	28·8	27·6	21·3	20·0	" squally wind.
" 15....	32·3	34·3	26·6	26·8	" " "
" 16...	30·8	33·5	12·8	13·1	Cloudy.
" 17....	30·6	29·2	19·2	15·9	Fair.
" 18....	29·9	32·8	20·2	20·3	Cloudy.
" 19....	29·0	34·1	24·5	24·1	"
" 20....	27·3	27·7	22·7	15·1	Fair.
" 21...	24·6	24·2	5·8	3·9	"
" 22....	20·6	23·5	9·0	8·2	" sleighing bad to date.
" 23....	23·6	24·1	20·0	20·7	Cloudy, no sleighing.
" 24....	23·6	31·6	20·6	21·5	" sleighing, but bad.
" 25....	36·0	33·0	29·9	31·2	" very squally wind.
" 26....	31·6	30·1	26·1	27·0	" snow.

MAXIMUM and Minimum Temperatures, &c.—*Continued.*

Date.	Thermometer Readings. Maximum. 6 a.m.	Maximum. 6 p.m.	Minimum. 6 a.m.	Minimum. 6 p.m.	Weather.
1905.	°	°	°	°	
Dec. 27....	28·3	26·6	21·9	16·2	Fair.
" 28....	24·0	25·9	15·7	18·8	Cloudy.
" 29....	22·3	23·0	2·5	1·3	Fair.
" 30...	17·1	18·2	8·0	7·5	" Lake Minnewanka frozen.
" 31....	11·8	5·8	— 6·1	— 9·4	"
1906.					
Jan. 1....	6·1	20·7	— 2·8	3·4	" squally wind.
" 2....	20·2	24·3	10·4	5·8	"
" 3....	25·0	32·3	18·4	24·7	" squally wind.
" 4....	33·6	37·1	24·0	29·2	Cloudy.
" 5....	29·6	22·6	18·8	15·6	Fair.
" 6...	15·8	20·6	4·7	8·9	Cloudy, ice on Bow about 12 inches.
" 7. ..	15·8	21·2	0·2	0·2	Fair, squally wind.
" 8....	26·8	30·8	16·5	24·9	Cloudy, sleighing only in few places, and that bad except on river.
" 9....	30·0	29·8	20·2	21·6	Cloudy.
" 10....	21·9	19·2	9·2	13·8	"
" 11....	17·8	9·1	— 1·7	— 4·2	Fair.
" 12..	10·3	20·1	5·2	8·5	"
" 13 ..	19·6	28·1	11·2	15·2	"
" 14....	22·9	23·9	9·5	7·7	" no sleighing.
" 15....	19·6	23·3	3·5	2·8	"
" 16....	17·4	18·3	0·7	3·0	Cloudy; snow, sleighing, but bad.
" 17....	21·4	27·0	14·8	16·8	Fair.
" 18....	21·6	19·6	1·0	3·0	Cloudy; snow, 5¼ in. snow on ground.
" 19....	16·8	— 2·3	—14·4	—20·2	Fair; sleighing good.
" 20....	— 6·6	— 9·2	—14·6	—18·5	" "
" 21....	9·0	19·1	—14·5	12·1	Cloudy "
" 22....	17·9	— 8·0	—20·4	—20·6	Cloudy; snow, sleighing good.
" 23....	4·5	40·0	—12·3	5·3	" snow; thaw; sleighing good.
" 24....	41·7	44·5	40·5	40·3	Fair; squally wind; thaw; sleighing good.
" 25....	43·9	45·6	40·7	40·7	Cloudy; thaw; chinook; sleighing good.
" 26....	42·9	40·3	27·5	24·3	Fair; sleighing bad.
" 27....	36·1	35·7	14·9	12·3	" "
" 28 ...	26·7	38·2	18·8	23·7	Fair; squally wind, sleighing bad.
" 29....	39·3	40·2	32·9	30·3	Cloudy; sleighing bad.
" 30....	36·9	46·1	31·8	34·1	Fair; squally wind; ice on Bow, 16 in.; thaw.
" 31....	43·0	47·0	38·4	39·8	Fair; no sleighing; thaw.
Feb. 1....	42·7	45·0	28·6	27·8	Fair; snow only in patches; perfect day.
" 2....	41·0	49·2	29·4	32·9	Fair; squally wind.
" 3.. .	43·7	28·0	23·8	9·7	" "
" 4....	9·7	27·3	0·4	0·6	"
" 5....	25·8	24·8	0·7	— 3·2	" perfect day.
" 6....	17·6	34·7	6·4	3·8	" "
" 7....	29·6	33·3	5·4	4·9	" "
" 8....	27·8	31·2	4·9	— 0·7	"
" 9....	24·6	24·9	3·3	7·1	"
" 10....	13·9	29·1	1·2	0·6	"
" 11....	24·8	23·2	12·8	10·3	"
" 12....	14·7	15·8	2·2	6·3	" snow.
" 13....	6·4	22·7	—15·1	—16·9	"
" 14...	17·7	26·1	— 5·6	— 6·0	"
" 15....	24·6	31·1	19·4	17·0	Cloudy.
" 16....	29·2	35·1	24·8	27·6	"
" 17....	33·2	40·2	29·3	28·7	Fair.
" 18....	40·2	41·1	35·4	35·2	Cloudy; rain and snow.
" 19.. .	34·9	35·9	31·7	30·8	"

Maximum and Minimum Temperatures, &c.—*Continued.*

Date.	Thermometer Readings. Maximum. 6 a.m.	Maximum. 6 p.m.	Minimum. 6 a.m.	Minimum. 6 p.m.	Weather.
1906.	°	°	°	°	
Feb. 20....	32·4	35·8	27·1	26·3	Cloudy.
" 21....	31·8	38·3	28·0	27·2	"
" 22....	29·5	38·2	24·0	23·8	"
" 23....	29·7	33·3	16·8	12·9	Fair.
" 24....	27·8	36·9	10·9	14·2	Cloudy.
" 25....	30·1	32·9	16·2	15·2	Fair.
" 26 ...	26·6	31·2	7·2	5·2	Cloudy.
" 27....	26·6	36·0	20·8	17·8	Fair.
" 28....	29·1	33·7	4·2	0·8	" ice on river about 15 in.; perfect day.
Mar. 1....	30·3	32·1	2·1	0·0	Cloudy.
" 2 ...	29·9	35·6	4·1	3·7	Fair.
" 3....	29·7	38·2	2·2	1·8	"
" 4....	32·0	42·9	20·5	20·9	"
" 5 ..	37·3	40·6	25·2	21·8	" squally wind.
" 6....	38·0	49·3	33·0	36·0	" "
" 7....	45·8	49·1	40·0	37·7	Cloudy; rain, robin.
" 8....	38·0	44·2	21·8	20·8	Fair.
" 9....	39·0	29·5	20·9	17·9	Cloudy.
" 10....	20·8	11·8	10·2	2·2	" squally wind.
" 11....	2·3	3·7	— 5·6	— 7·5	"
" 12....	0·0	0·7	—12·0	— 7·3	" "
" 13....	— 1·2	— 0·8	— 7·2	— 8·4	Cloudy.
" 14....	— 1·8	13·9	—19·8	—20·3	Fair.
" 15....	11·8	28·2	—14·0	—15·4	"
" 16 ...	25·0	30·3	0·5	— 2·2	"
" 17...	27·2	19·8	10·8	11·0	Cloudy; snow.
" 18....	16·0	15·3	5·5	5·3	Fair.
" 19....	11·3	28·1	—10·5	—10·4	" squally wind.
" 20....	25·0	38·2	4·2	6·7	" "
" 21....	35·1	41·8	3·3	1·4	" perfect day.
" 22....	39·0	47·6	15·4	18·5	Cloudy.
" 23....	41·0	45·2	29·6	28·7	Fair.
" 24....	41·8	53·4	27·5	29·1	"
" 25....	47·3	50·9	25·8	25·1	" river breaking up.
" 26 ...	44·0	51·0	27·4	27·7	"
" 27....	47·3	52·4	22·2	21·0	"
" 28....	46·2	51·3	25·7	27·8	"
" 29....	47·2	53·2	21·3	21·3	"
" 30....	48·2	59·7	28·8	29·5	"
" 31....	55·7	53·5	39·8	38·7	Cloudy.
April 1....	46·0	35·9	32·3	30·2	Cloudy, no snow on ground.
" 2....	34·0	41·8	26·8	26·7	Fair, junco, ice out of river.
" 3....	38·7	56·8	18·8	18·5	"
" 4....	53·3	57·6	31·4	33·2	" mosquitoes.
" 5....	53·1	55·6	26·9	30·8	Cloudy, Arctic bluebirds.
" 6....	53·1	61·1	36·5	35·8	Fair, squally wind.
" 7....	55·2	52·5	42·8	34·3	Cloudy, rain and snow.
" 8....	37·7	47·7	30·3	30·9	Fair, river rising.
" 9....	43·7	43·7	31·8	31·9	" squally wind, rain and snow.
" 10....	38·3	44·8	29·7	30·2	" " "
" 11....	41·8	42·2	26·9	28·1	" " "
" 12....	24·3	45·5	17·6	16·8	" perfect day.
" 13 ...	42·3	52·3	21·2	20·8	" squally wind.
" 14....	48·0	57·3	24·8	24·4	" "
" 15....	53·0	63·9	33·4	33·8	" various birds, butterflies.
" 16....	58·5	59·6	32·2	32·8	Cloudy, rain.
" 17....	46·2	44·5	34·3	33·2	" rain and snow.
" 18....	41·2	52·4	26·3	26·3	Fair, squally wind.
" 19....	50·0	56·4	43·0	43·0	" "
" 20....	50·0	63·9	44·3	43·7	" frogs croaking.
" 21....	59·7	73·1	30·9	30·9	"
" 22....	67·2	66·9	33·2	33·2	" thunder.

MAXIMUM and Minimum Temperatures, &c.—*Continued.*

Date.	Thermometer Readings. Maximum. 6 a.m.	Maximum. 6 p.m.	Minimum. 6 a.m.	Minimum. 6 p.m.	Weather.
1906.	°	°	°	°	
April 23	59·9	48·8	30·7	33·1	Cloudy, rain, smoke from bush fire.
" 24	44·2	52·9	31·0	31·1	" no smoke.
" 25	48·9	49·2	29·7	29·3	" rain.
" 26	44·2	58·3	27·3	27·2	Fair.
" 27	51·2	49·8	25·4	26·0	Cloudy.
" 28	44·0	55·7	34·3	34·2	Fair.
" 29	54·4	67·4	23·9	23·8	"
" 30	62·2	66·9	30·0	29·7	" much smoke.
May 1	61·5	46·7	38·1	37·9	Cloudy, rain.
" 2	42·5	59·9	32·8	35·2	"
" 3	53·0	50·3	37·7	38·3	"
" 4	38·3	46·0	21·5	21·8	"
" 5	41·8	49·4	19·8	19·9	Fair.
" 6	44·3	44·6	29·2	28·9	"
" 7	38·2	56·5	26·2	27·3	"
" 8	53·0	67·2	23·7	25·0	"
" 9	63·0	74·3	36·0	36·3	" forest fire.
" 10	69·2	74·5	42·8	43·6	"
" 11	60·0	65·6	36·0	35·7	" much smoke.
" 12	60·0	58·0	43·2	42·3	" rain.
" 13	54·0	56·7	36·8	37·3	Cloudy.
" 14	53·2	61·2	36·2	36·1	"
" 15	55·2	44·0	39·8	37·5	" rain.
" 16	37·7	41·7	33·7	33·3	" "
" 17	41·2	51·4	34·8	34·7	" "
" 18	49·3	52·2	34·2	34·2	" "
" 19	48·8	60·1	28·9	29·8	" "
" 20	52·2	62·3	36·7	36·6	Fair.
" 21	59·2	46·2	39·5	35·1	Cloudy, rain.
" 22	34·9	42·4	32·3	32·6	" rain and snow.
" 23	42·1	47·3	26·6	27·8	" rain.
" 24	40·0	50·4	34·1	34·0	" "
" 25	48·1	41·7	36·6	35·3	" "
" 26	38·5	43·1	33·4	34·3	"
" 27	35·9	51·3	29·3	30·7	Fair.
" 28	46·2	48·7	34·3	35·2	Cloudy.
" 29	45·0	44·9	37·8	38·8	" rain.
" 30	40·0	54·3	34·8	35·8	"
" 31	49·8	63·8	28·4	28·8	Fair.
June 1	59·1	65·4	38·2	38·0	"
" 2	61·4	67·1	35·3	36·8	"
" 3	64·5	72·4	33·3	34·5	"
" 4	67·7	63·5	48·3	44·2	Cloudy, rain.
" 5	45·9	60·5	37·8	40·6	Fair.
" 6	56·5	60·2	34·4	35·7	Cloudy, rain.
" 7	57·2	51·3	41·9	44·0	"
" 8	48·5	57·3	40·9	40·6	"
" 9	55·1	66·8	32·9	35·4	" rain.
" 10	56·4	69·0	35·8	35·8	Fair.
" 11	61·4	68·1	37·4	38·9	Cloudy.
" 12	68·0	63·4	47·6	48·3	" rain.
" 13	51·4	58·3	40·7	43·3	" "
" 14	49·6	56·5	40·7	41·7	" "
" 15	51·3	52·3	30·7	30·7	" "
" 16	42·0	60·9	37·7	39·1	Fair.
" 17	57·9	54·3	41·2	41·3	Cloudy, rain.
" 18	51·9	60·3	37·2	37·8	Fair.
" 19	54·1	56·9	42·8	44·3	Cloudy.
" 20	56·0	61·1	28·2	30·2	Fair.

Maximum and Minimum Temperatures, &c.—*Continued.*

Date.	Thermometer Readings.				Weather.
	Maximum.		Minimum.		
	6 a.m.	6 p.m.	6 a.m.	6 p.m.	
1906.	°	°	°	°	
June 21...	59·3	55·0	33·2	36·7	Cloudy, rain.
" 22 .	49·5	54·3	35·8	36·0	" "
" 23....	53·3	70 8	30·2	30·8	Fair.
" 24....	68·0	78·5	33·5	35·1	"
" 25....	74·1	81·6	40·2	40·5	" rain.
" 26....	64·6	75·9	47 2	48·2	"
" 27....	73·0	70·5	46·8	49·1	Cloudy, rain.
" 28...	54·9	60 3	47·7	48·1	" "
" 29....	53·9	55·5	41 0	42·9	Fair
" 30 ...	50·9	66·9	42·6	44·1	"

N. B. SANSON,
Observer.

PART VII.

YUKON TERRITORY.

YUKON TERRITORY.

No. 1.

REPORT OF THE COMMISSIONER.

DEPARTMENT OF THE INTERIOR,
DAWSON, Y.T., July 2, 1906.

The Hon. FRANK OLIVER,
Minister of the Interior,
Ottawa.

SIR,—I have the honour to submit the Annual Report for the Yukon Territory for the year ending June 30, 1906.

The gold yield for the past year amounted to $6,539,402.85. This was less than the preceding year. The decrease is to be accounted for by (*a*) the lack of water, due to the exceptionally dry summer, and (*b*) the fact that many mining properties were not worked pending the installation of dredges and expensive hydraulic plants. This latter cause, while it makes the permanency of the Klondike as a gold producing country certain and will inevitably in the near future increase the output enormously, may, for another year, continue to prevent a large output.

The methods of placer mining in the territory are quickly changing. The cruder methods of working the ground are disappearing and in their stead the auriferous gravels are being worked more extensively and economically by means of hydraulic plants and dredges. Large hydraulic plants have been started and in some cases finished during the past year, and several dredges have been installed and proven to be a great success. The operations of the dredges have proven so conclusively that the ground is suitable for this manner of working that many new dredges have been ordered, so many in fact that the manufacturers cannot fill all the orders this year. The deposits of gold bearing gravel, which can be treated by dredging and hydraulicking, are so extensive that placer gold mining in the Yukon is absolutely assured to be a vast and permanent industry. While much of the gold-bearing gravels will be worked and must be worked by such means, involving the investment of considerable capital, it would be an undoubted mistake to conclude that there are no inducements left for the individual prospector and miner. On the contrary, the Stewart, Pelly, MacMillan, Kluane and many other sections abound in most alluring prizes and will some day give rise to other 'Klondikes.'

Quartz mining has received much attention throughout the territory, and has been particularly active in the southern end, in the vicinity of Conrad city, on Windy Arm. A large amount of development work has been done there and the prospects are most promising. I visited the claims in September and was surprised at the amount of work done and the size and richness of the ledges.

The council of the Yukon Territory met on the 24th of August and prorogued on the 9th September, 1905. During the session a number of ordinances were passed dealing with local matters, and much other business was transacted. Three committees were appointed to act after the close of the session to take steps looking to a mining code, a lien for miner's wages and a general water system. The committees faithfully performed their work and made appropriate representations to the government at

Ottawa. In accordance with the recommendations of these committees, it is satisfactory to note that the Governor in Council has passed an ordinance giving a lien to miners for wages, that the mining code drawn up by the committee has been presented to parliament in the form of a Bill, and that you have instructed officials of your department to inquire fully on the ground into the extent of the gravels available for a general water system should such be installed.

I trust the mining code will be accepted by parliament, as its passage will do much to render mining conditions more stable and induce the investment of capital.

The necessity of a general water system is well understood by all who know the country, and I would urge that in this matter too, the well considered advice of the Yukon Council as contained in a memorial to the Governor in Council, dated January 27, 1906, be acted upon.

On February 2 I left Dawson for Ottawa to consult with the government regarding some important matters affecting the welfare of the Yukon. I returned here on June 6. Upon my return I found that the work of my office had been carried on in a most gratifying manner by the Acting Commissioner, Mr. J. T. Lithgow.

The finances of the territory are in splendid condition. For the year ending June 30, 1905, the revenue was $389,629.97 and the expenditure was $454,390.52, leaving a deficit of $24,530.37. For the past year the revenue was $371,476.49 and the expenditure was $308,849.47, leaving a surplus of $62,627.02. Economy has been exercised wherever possible without interfering with the efficiency of the public service or works.

The Yukon Territory during the past year has been practically without crime. This happy condition, however, is not unique as it has prevailed in the territory from its earliest history. This is due and has been due to the remarkably law-abiding disposition of the citizens, and in a measure also, to the splendid administration of justice and the untiring vigilance of the Royal Northwest Mounted Police, under the efficient command of Major Wood.

The past year saw a large number of tourists and investors visit the territory. The country with its delightful summer climate, perfect order and social advantages, was a revelation to them. Notable among these visitors was a large party of members of the American Institute of Mining Engineers. They were extended courtesies by the government and citizens, and were afforded every opportunity to study and understand the country. They manifested a deep interest in the economic conditions of the territory, and already the favourable effects of their visit can be noticed.

It is also pleasant for me to record that you visited Dawson from August 26 to September 1, being the first Minister of the Crown to honour this section of the Dominion with a visit. I would respectfully urge that you avail yourself of the earliest opportunity to revisit the territory and remain for a more extended period ; and that your colleagues be also urged to come and gain a personal knowledge of the requirements and possibilities of this rich country.

In conclusion I can say that the future of the Yukon never looked brighter. Mining in the older parts is fast passing through the transition stage. Dredging and hydraulicking have been demonstrated to be successful and millions of capital are now being invested in these methods of extracting the gold from our gravels. Virgin fields also are in plenty. They are attracting individual prospectors, and hundreds of miners who stampeded to the new diggings of Alaska are returning to the 'Mother of the Golden North.' Throughout the whole territory there are sure evidences of an era at hand of great and permanent prosperity.

I have the honour to be, sir, your obedient servant,

W. W. B. McINNES,
Commissioner.

No. 2.

REPORT OF THE TERRITORIAL SECRETARY.

DAWSON, Y.T., August 23, 1906.

The Hon. FRANK OLIVER,
Minister of the Interior,
Ottawa.

SIR,—I have the honour, by direction of the Commissioner, to forward to you inclosed reports of the following officers of the government of this Territory :

Gold Commissioner ;
Assistant Gold Commissioner ;
Crown Timber and Land Agent ;
Comptroller ;
Director of Surveys.

I have the honour to be, sir, your obedient servant,

C. B. BURNS,
Territorial Secretary.

No. 3.

REPORT OF THE GOLD COMMISSIONER.

DAWSON, Y.T., July 28, 1906.

The Hon. W. W. B. McINNES,
Commissioner Yukon Territory,
Dawson.

SIR,—I beg to submit my annual report for the year ending June 30, 1906.

During the year 53 protests have been issued by the Clerk of the Gold Commissioner's Court.

This is a decrease from the previous years, the number for the year ending June 30, 1905, being 137 ; for the year ending June 30, 1904, there were 84, and for the previous year again there were 99.

All protests were heard at Dawson with the exception of two, heard at Mayo Landing on the Stewart river.

The decrease in the number of protests is due to the conflict of claims on the old creeks getting more and more settled as time goes on. The change in the regulations as to the side boundaries of claims has, I consider, also tended to minimize disputes, as it does away with the opportunity of hill or bench claims encroaching on the creek bottom, as they did formerly under the very indefinite boundary line of 'base of the hill' or 'rimrock.'

I have the honour to be, sir, your obedient servant,

E. A. SENKLER,
Gold Commissioner.

No. 4.

REPORT OF THE ASSISTANT GOLD COMMISSIONER.

DAWSON, Y.T., July 16, 1906.

The Hon. W. W. B. McINNES,
Commissioner of the Yukon Territory,
Dawson, Y.T.

SIR,—I have the honour to submit herewith the annual financial report of the Gold Commissioner's Office, Yukon Territory, for the fiscal year ending on the 30th June last, which embodies the revenue of the head office at Dawson for the fiscal year in question ; and also the revenues received at this office during the last fiscal year from the offices of the Mining Recorders outside of the Dawson Mining District.

At the same time I beg to submit herewith inclosed for your information and for the information of the department a comparative statement between the fiscal year in question and the previous one ; and also a statement showing the number of instruments issued in connection with the said revenues.

The total receipts amount to $120,563.26.

As you will see by the said comparative statement there is a decrease of $25,467.47 from the total receipts of the corresponding period of the previous year.

The largest portion of the decrease in question is accounted for by the reduction in the rate of free miners' certificates from $7.50 to $5 per annum ; and also by the fact that since the 7th October last, inclusive, free miners' certificates were issued to expire on the 30th June, 1906, and that only a proportion of the fee of $5 was charged, according to the provisions of section 1 of the Order in Council of the 31st July last, amending the Placer Mining Regulations in that respect.

There is also a slight decrease in the amount received from renewal fees and from certificate of work fees, which decrease is accounted for by the fact that a number of claims have been allowed to lapse so as to be incorporated in extension of side or rear boundaries of adjoining claims under the provisions of section 12 of the Placer Mining Regulations ; or so as to be relocated under the provisions of the regulations which came in force on the 7th October last, increasing the size of hill and bench claims from 500 feet to 1,000 feet.

There is also a slight decrease in the amount of fees received from relocation grants ; and in the amount of fees received from new location grants ; and from the recording of documents regarding placer mining claims. There has been, however, on the other hand, a substantial increase in the receipts of fees under the Quartz Mining Regulations in the Whitehorse Mining District.

Notwithstanding the decreases hereinabove mentioned in the revenues collected under the Placer Mining Regulations, there has been very little difference in the amount of clerical work connected therewith.

During the fiscal year ending 30th June last an important change has been made by the Department of the Interior in dividing the Yukon Territory into two divisions, viz., the Dawson Mining Division and the Whitehorse Mining Division, at Yukon Crossing, and in appointing Mr. R. C. Miller, who has been the Mining Recorder at Whitehorse since 1899, as an Assistant Gold Commissioner for the Whitehorse Mining Division.

The office of the Mining Recorder at Clear creek was closed on the 30th ultimo, and that portion of said Clear Creek district comprised within the watershed of the Mc-

Questen river has been incorporated in the Duncan Mining district, and the balance of said district has been incorporated in the Dawson Mining district.

It was also decided at the same time to re-establish the Sixtymile Mining district, which was abolished on the 31st January, 1905, and a mining recorder will take charge of this new office in a few days.

The abolishing of the Clear Creek Mining district was brought about by the fact that a very small number of claims are now in good standing on Clear creek and its tributaries ; and the re-establishment of the said Sixtymile Mining district has been brought about by the fact that the Royal Northwest Mounted Police authorities decided last winter to close their detachment on Glacier creek, and it was, therefore, by reason of the large number of claims then in good standing in that locality, decided to appoint a mining recorder to transact the affairs of the miners in that locality.

The Duncan Mining district has given much encouragement to the miners interested in that part of the country during the last fiscal year, especially on Highet creek.

The Kluane Mining district has not undergone any material change since the date of my report for the fiscal year ending June 30, 1905.

As regards the Whitehorse Mining district, a large number of quartz mineral claims have been staked and recorded in the Windy Arm portion of said district, and a large amount of development work was done during the last fiscal year.

As regards the matter of hydraulic mining leases, several of those leases were cancelled during the fiscal year ending 30th June last, viz. :

1. Lease No. 22, issued on the 29th March, 1901, in favour of Mr. William MacIntosh, for an hydraulic mining location, situated on the left limit of Dominion creek, in the Indian River Mining Division, commencing at a point opposite the left limit of creek claim No. 210 below lower Discovery, thence down stream one mile, which location was thrown open for occupation and entry on the 20th November last ;

2. Lease No. 32, issued on the 15th October, 1901, in favour of Messrs. George Foote Washburne and Peter Reid Ritchie, for an hydraulic mining location situated on Kirkman creek, a tributary of the Yukon river, commencing at the upper boundary of Discovery claim on said creek, thence down stream for five miles in direct distance, which location was thrown open for occupation and entry by free miners on the 31st January last ;

3. Lease No. 40, issued on the 25th June, 1902, in favour of the Klondike Consolidated Gold Fields, Limited, for an hydraulic mining location, situated on the Lewes river, in the Yukon Territory, commencing at a point on said river, about four and one-half miles in direct distance, above the mouth of Big Salmon river, thence up stream three miles more or less, by half a mile in depth, on either side of the said Lewes river, which location was thrown open for occupation and entry by free miners on the 19th February, 1906 ;

4. Lease No. 35, issued on the 25th February, 1902, in favour of the North American Transportation and Trading Company, for an hydraulic mining location situated on Indian river, in the Yukon Territory, commencing at a point two and a half miles below the mouth of Quartz creek, thence down stream a distance of two and a half miles, which location was thrown open for occupation and entry by free miners on the 12th February, 1906 ;

5. Lease No. 41, issued on the 18th September, 1902, in favour of the North American Transportation and Trading Company, for an hydraulic mining location situated on Indian river, in the Yukon Territory, commencing at the junction of Quartz creek with Indian river, thence down stream two and a half miles, which location was thrown open for occupation and entry by free miners on the 27th November last ;

6. Lease No. 42, issued on the 18th September, 1902, in favour of the North American Transportation and Trading Company, for an hydraulic mining location therein described as situated on the Stewart river, in the Yukon Territory, commencing at a point on the Stewart river three-quarters of a mile below the junction of the Mc-

Questen river with the Stewart river, thence down the said Stewart river five miles, more or less, which location was thrown open for occupation and entry by free miners on the 20th December last.

Besides the above cancellations, the Minister of the Interior issued on the 30th April last notices of cancellation of the following leases, viz.: Lease No. 1, issued on the 12th February, 1900, in favour of the Klondike Government Concession, Limited, for an hydraulic mining location, situated on Hunker creek, in the Yukon Territory; No. 5, issued on the 3rd November, 1899, in favour of the Honourable E. H. Bronson and Mr. C. C. Ray, for an hydraulic mining location, situated on Bonanza creek, in the Yukon Territory ; lease No. 10, issued on the 16th March, 1900, in favour of Mr. Joseph W. Boyle, for an hydraulic mining location, situated on Quartz creek, in the Yukon Territory ; lease No. 16, issued on the 23rd October, 1900, in favour of Mr. Ernest B. Scroggie, for an hydraulic mining location, situated on Scroggie creek, in the Yukon Territory ; lease No. 20, issued on the 8th November, 1901, in favour of Mr. Edward L. Ensel, for an hydraulic mining location, situated on Eureka creek, in the Yukon Territory ; lease No. 33, issued on the 16th October, 1901, in favour of Messrs. George Foote Washburne and Peter Reid Ritchie, for an hydraulic mining location, situated on Gold Bottom creek, in the Yukon Territory.

The ground comprised within the said leases Nos. 1, 5, 10, 16, 20 and 33 has, however, been closed from placer mining entry by special Order in Council pending further determination in that regard.

On the other hand, the following hydraulic mining leases were issued by the department during the fiscal year ending 30th June last, viz.: lease No. 47, issued on the 30th August, 1905, in favour of Mr. William Charles Thompson, for an hydraulic mining location therein described as situated on Dublin Gulch, a tributary of Haggart creek, in the Yukon Territory (Duncan Mining district); lease No. 45, which was forwarded by the Department of the Interior for the signature of the lessees, Messrs. James Ollason and A. J. Green, of a tract of land situated on the ancient bed of the Stewart river, in the Yukon Territory.

I have the honour to be, sir, your obedient servant,

F. X. GOSSELIN,

Assistant Gold Commissioner.

No. 5.

REPORT OF THE CROWN TIMBER AND LAND AGENT.

DAWSON, July 5, 1906.

The Hon. W. W. B. McINNES,
Commissioner of the Yukon Territory,
Dawson, Y.T.

SIR,—I have the honour to submit herewith my report for the year ending June 30, 1906.

Attached hereto please find :

A. Statement of receipts from timber, hay, grazing land and coal royalty.

B. Statement of revenue derived from Dominion lands.

C. Statement showing timber and hay permits issued.

The revenue has decreased $9,446.84.

In the Crown Timber Branch....	$4,337 81
In the Dominion Lands Branch....	5,109.03
	$9,446 84

The decrease in the Timber Branch applies to royalty and to hay permits, and is due to the falling off in sales of lumber and to a lesser number of hay permits having been issued. Timber permits show a slight increase over last year, and this is due to the fact that permits have been issued for the cutting of sawlogs, this latter fact accounting at the same time to some extent for the reduction in royalty. Wood as fuel is being replaced by coal and this too partly accounts for the reduction in royalty on timber.

There is an increase of nearly $1,000 in seizures, which is not to be considered as due to a tendency among millmen and wood-choppers to evade the laws, but rather to the fact that there have been cases where men have cut wood under contract for mining operations, but, before delivery, the mining operations had ceased for one reason and another, and the wood was offered for sale to others. The office became aware of a few such instances, and as no permits had been taken for the wood it was dealt with under the head of seizures, but, on account of its having been cut in good faith for mining purposes, the ordinary fee of 50 cents per cord, with an office fee of $5, was charged in each case. Wood contractors do not realize that wood can be cut free only by a free miner for mining purposes and that the moment it is offered for sale it becomes subject to dues.

There were 43 square miles of timber lands applied for, under seven applications, none of which have been dealt with on account of the instructions which you issued September 8, 1905, suspending the operation of the Timber Regulations. Had it not been for such suspension the reduction in revenue from timber would not have been as great as it is.

During the year royalty has been collected on 5,503 tons of coal; a further 3,000 tons have been mined by the lessees of group lot 10 and lot 11, group 10, Y.T., near Tantalus, royalty on which will be paid during the current year; 4,000 tons or more have been mined from property purchased under the old regulations by which $20 an acre was charged for bituminous coal lands, and in which no provision for royalty was made.

The revenue from Dominion lands sales decreased $1,135.05. This is due to the suspension of the Lands Regulations, per your instructions of September 8, 1905, instructing me not to dispose of lands outside of townsites until further advised. Only in June were these instructions rescinded, and then only in so far as they applied to lands which were not suitable for agricultural purposes. However, a few applications for lands were approved by you, during the month of June, and only in one instance, that of an application for one acre of land, has the purchase price been paid.

There were 56 applications for land received, covering a total of 4,163½ acres.

An area of 425½ acres, covered by seven applications, has been sold.

An area of 196½ acres, covered by three applications, has been cancelled, leaving 3,541¾ acres, covered by forty-six applications, which are now in abeyance pending the receipt of the new regulations from the department before being dealt with.

Twelve applications have been made for coal lands, covering a total area of 2,399 acres; seven applications covering 1,360 acres have been cancelled, and five applications, for a total of 1,039 acres, are now being dealt with.

A few applications by lessees to relinquish waterfront held by them at Dawson were granted, and this has caused quite a reduction in the rentals.

The work of this office has not decreased, but it has been systematized so as to allow of its being handled by a reduced staff. During the year 1903-04, when the revenue was $72,252.65, the expenditure for salaries and living allowance charged to this office was $22,800. To-day my staff is composed of a clerk, who is also a stenographer, and one timber inspector, whose salaries and allowances, together with mine, amount to only $8,700 per annum.

All of which is respectfully submitted by your obedient servant.

H. M. MARTIN,

Crown Timber and Land Agent.

YUKON TERRITORY.

A.—Revenue from Timber, Hay, Grazing and Coal Lands during the Year ended June 30, 1906.

1905-1906.	Bonus.	Royalty.	Timber Permits.	Seizures.	Fees for Inspection.	Hay Permits.	Grazing Land.	Coal Royalty.	Total.
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
July	1,000 00	1,040 17	918 50	417 66	20 00	73 50	4 97	163 00	3,637 80
August	45 00	1,399 58	344 00	235 64		64 00			2,088 22
September		583 84	210 50	357 14					1,151 48
October		1,034 12	1,206 00	839 25				231 20	3,310 57
November		286 99	235 00	57 50				28 60	608 09
December		180 71	725 00	28 00					933 71
January		74 08	287 50	17 00					378 58
February		248 83	191 00	29 00					468 83
March		289 21	1,822 50	99 00					2,210 71
April		1,451 31	745 00	380 37			5 03		2,581 71
May		1,192 67	35 00	97 75		40 00		127 50	1,492 92
June		456 67	549 25	105 00		17 00			1,127 92
	1,045 00	8,238 18	7,269 25	2,663 31	20 00	194 50	10 00	550 30	19,990 54

H. M. MARTIN,
Crown Timber and Land Agent.

B.—Revenue from Dominion Lands During Year ended June 30, 1906.

1905–1906.	General Sales.	Rentals.	Registration Fees.	Patent Fees.	Survey Fees.	Total.
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
July	457 61	215 25				672 86
August	339 55	7 09	2 50			349 14
September	98 09	958 10	28 50			1,084 69
October	1,309 29		5 00			1,314 29
November	77 09	8 28	2 00			87 37
December	349 65	9 28				358 93
January		413 21	4 00			417 21
February	52 27		5 00			57 27
March	828 66		2 00		100 00	930 66
April	130 31	485 31				615 62
May	230 21	8,240 26	4 50			8,474 97
June	129 26	1,444 64				1,573 90
	4,001 99	11,781 42	53 50		100 00	15,936 91

H. M. MARTIN,
Crown Timber and Land Agent.

C.—Timber and Hay Permits Issued during Year ended June 30, 1906.

Kind.		No.	Quantity.	
Timber	Cordwood	119	11,593 cds.	
	Sawlogs	6		210,000 feet
	House logs			
Hay		30	155½ tons	

H. M. MARTIN,
Crown Timber and Land Agent.

No. 6.

REPORT OF THE COMPTROLLER.

COMPTROLLER'S OFFICE,
DAWSON, Y.T., July 23, 1906.

The Hon. W. W. B. McINNES,
Commissioner of the Yukon Territory,
Dawson, Y.T.

SIR,—I have the honour to submit my eighth annual report, for the year ending June 30, 1906.

The expenditure under the vote, 'Administration of the Yukon,' through the Department of the Interior disbursed through my office was $168,357.54, monthly statements with vouchers being sent to the department.

The local revenues and expenditures of the Yukon Territory for the year were: revenue, $371,476.47; expenditure, $308,849.47, administered through my office; a copy of the report is attached thereto. Quarterly statements were sent to the Auditor General as required by Order in Council.

The disbursements for the Department of Justice were $29,111.90 for services in connection with this territory, monthly statements being forwarded with vouchers.

For the Department of Indian Affairs, the expenditure was $6,419.04, of which $3,000 was for schools and $3,419.04 for the relief of sick and destitute Indians, &c.

The management of the expenditure of the Department of Public Works, 'Buildings,' has, as heretofore, been vested in the Superintendent of Public Works and myself; the expenditure was $74,650.93.

The expenditure for the Department of Public Works, 'River Improvements Vote' was $13,962.08, the credit being in the name of the Commissioner and myself.

The total royalty collected in the territory for the year was $163,487.31—Dawson $161,359.56, Whitehorse, $2,119.12, and Fortymile, $8.63.

The receipts from free certificates issued to exporters of American gold-dust were $381.50. The revenue was forwarded to the credit of the Receiver General, the drafts being sent to the department weekly and statements monthly.

The revenue from law stamps, Yukon Territorial Court was $5,517.50; from mining court stamps, $753.25, drafts and statements being forwarded to the Department of Inland Revenue.

Monthly statements from the Gold Commissioner's and Crown Timber and Land Agent's Offices have been checked each month as heretofore and the returns forwarded to the Department of the Interior; the suspense account checked and the cheques countersigned in payment of withdrawals.

The management of the affairs of the city of Dawson has been vested in my office during the past year; a copy of the financial report is attached herewith.

Your obedient servant,

J. T. LITHGOW,
Comptroller.

No. 7.

REPORT OF THE DIRECTOR OF SURVEYS.

SURVEY OFFICE, YUKON TERRITORY,
DAWSON, Y.T., June 27, 1906.

The Hon. W. W. B. McINNES,
Commissioner,
Yukon Territory.

SIR,—I have the honour to submit the annual report of the operations of the Survey Office for the year ending June 30, 1906, as follows :—

The employees of this office during the past year were James Gibbon, D.L.S., P. F. X. Genest, draughtsman, and myself.

Mr. Gibbon was employed during the whole of last season in making a phototopographical survey of the Klondike watershed, which he was unable to complete on account of the season closing in. I would respectfully recommend that this survey be completed during this present season. Mr. Gibbon filled the position of director during my absence last winter. In April, May and part of June he surveyed 23 miles of base line on Barker creek and its tributaries, and 40 miles of traverse of the Stewart river.

Plans of the following surveys were filed in this office during the year and include the surveys made by the surveyors in private practice in the territory :—

Group lots 38 (including 25 quartz claims).
Advertised placer claims, 20.
Base lines, 6.
Hydraulic concessions, 3.
Auction claims, 6.
Subdivisions, 2.
Reference traverse, 1.
Two plans of 69 placer claims in Matson and Doyle concession.

Mr. Genest has been employed in general draughting work, copying and compiling plans and sketches and making blue-prints, &c., for the public for much of which charges have been made. The practice of making plans and blue-prints from the office records to *bona fide* prospectors and investors, free of charge has been followed more liberally this year than formerly.

Mr. H. G. Dickson, D.L.S., of Whitehorse, surveyed under contract for the department, 12 miles of reference traverse in the Windy Arm mineral belt, and 15 miles of base line on Burwash creek in the Kluane district. Returns for this last survey have not yet been received but Mr. Dickson has notified this office that the work has been completed.

I have the honour to be, sir, your obedient servant,

C. W. MACPHERSON,
Director of Surveys, Y.T.

PART VIII

SUPERINTENDENT OF MINES

REPORT OF THE SUPERINTENDENT OF MINES.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SUPERINTENDENT OF MINES,
OTTAWA, August 15, 1906.

The Hon. FRANK OLIVER, P.C.,
Minister of the Interior,
Ottawa.

SIR,—I have the honour to submit herewith the report of the operations and conduct of the Mines Branch for the fiscal year ended June 30, 1906.

MINERAL RESOURCES.

Owing to the general need of reliable information regarding the mineral resources of Canada as evidenced by the numerous applications made to this office for such information, the Mines Branch has undertaken the publication of a series of reports on the economic minerals of Canada, giving for each mineral the location, mode of occurrence, exploitation, treatment and such other information as may be of interest and value to the investor and mining engineer. The commencement of this undertaking was made with two reports :

1st. Mica, its occurrence, exploitation and uses ;

2nd. Asbestos, its occurrence, exploitation and uses.

The editions of these reports, which were ready for distribution in the autumn of 1905, are now nearly exhausted.

A report on *graphite,* giving all available information on this mineral, is now in preparation.

IRON ORE DEPOSITS.

A commencement has been made of the systematic investigation of the iron ore deposits of Canada, covering for the present season the deposits of Nova Scotia, of Western Ontario and the country along the Ottawa valley.

The field party in Nova Scotia is in charge of Dr. Woodman, Professor of Geology, Dalhousie College, Halifax ; that of Western Ontario is in charge of Mr. F. Hille, M.E., Port Arthur ; and that along the Ottawa valley in charge of Mr. Fritz Cirkel, M.E., of Montreal.

The following are the items of information to be covered by the investigation :—

1. Localities of iron ore deposits so far discovered, with names and addresses of owners.

2nd. History of development of mines and companies, if any.

3rd. Geological features so far as necessary for comprehension of the nature of the ore deposits.

4th. Analyses of properly selected ore samples.

5th. In case of mines which have been worked, output and statistics.

6th. Transportation facilities.

7th. Water-powers in neighbourhood of ore deposits ; height of fall and amount of water discharged.

8th. Limestone deposits in neighbourhood of deposits.

9th. The character of forest in neighbourhood of deposits and amount of wood supply suitable for mining purposes and the production of charcoal in the event of the introduction of electric smelting.

10th. Maps of mines and drill holes, if any.

11th. Description of the topography of the ore fields as to suitability for magnetic surveys.

The field to be covered is extensive and, therefore, only those deposits will at present be considered which are located either in the vicinity of transportation lines, water or rail, or in localities easy of access and to which branch lines could be cheaply constructed to existing transportation lines.

This investigation undertaken in the interests of the iron industry of Canada will require many seasons' work to cover satisfactorily the more important iron ore deposits. The results of the investigations will, however, be published at the rate at which the survey proceeds.

MAGNETIC SURVEYS.

It is the intention to make magnetic surveys of all important magnetite ore fields, the terrain of which is suitable for this class of work.

The method of delimiting magnetite deposits by magnetometric measurements, although practised for many years in Sweden, is new in this country and without special training in the use of this method by laboratory practice very erroneous conclusions are apt to be drawn from the intensity curves obtained as the result of field measurements. To furnish facilities for this needed laboratory practice for training members of the staff to apply this method successfully an experimental plant has been designed and constructed. The rooms at present occupied by the Mines Branch are, however, entirely unsuitable for this work. The many conductors running in Sparks street parallel to the rooms and carrying heavy fluctuating currents produce a rapidly varying magnetic field, which prevents the needle of the magnetometer from coming to rest. A proper room free from these magnetic disturbances is urgently needed for the setting up and use of this apparatus.*

There are at present many and urgent applications for magnetic surveys of magnetite deposits on file in this office. The staff of the Mines Branch, consisting at present of only two persons competent to do this work, is entirely insufficient to meet this demand, more especially since even these cannot be sent into the field on account of the large amount of office work entailed by the preparation for the press of the two reports on the electric smelting experiments and the report of the Zinc Commission, which latter by your instructions was not to be delayed.

On account of the inability of owners of magnetic ore deposits to find engineers competent to apply this method, the request of private parties to have such work done for them by the government is reasonable, since it is one of the functions of the government to assist in the development of the country's resources by doing a class of work which owners of properties cannot do for themselves.

FIELD WORK.

This summer Mr. E. Lindeman, M.E., has been temporarily engaged to make a magnetic survey of the Glendower iron range, which is now in progress. If time permits, he will make further surveys of the iron ore deposits along the Kingston and Pembroke Railroad.

During the summer of 1905 magnetic surveys were made of the Wilbur mine and of the Belmont iron mine by Mr. B. F. Haanel, B.Sc. The following are his reports :—

---

* Arrangements have since been made for the removal of the Mines Branch to the Thistle Building on Wellington street.

Dr. Eugene Haanel,
Superintendent of Mines,
Department of the Interior,
Ottawa.

Sir,—In accordance with your instructions I made magnetic surveys of the following properties :—

1st. *Wilbur Mine.*—This mine, the property of W. Caldwell, Esq., is situated on lots 3 and 4, concessions 12 and 13, township of Lavant, Lanark county, province of Ontario, and is connected with the Kingston and Pembroke Railroad by a branch line running through the mine.

A base line was cut through in the direction northeast, southwest, the approximate direction of the strike of the ore formation. This base or principal line was divided into 30-foot spaces and cross lines run at right angles from these divisions 500 feet on either side of the base line. These cross lines were in turn divided into 30-foot spaces. Thus the field was divided into squares 30 feet on the side, for a length of 2,500 feet and a width of 1,000 feet.

Magnetometric readings (both vertical and horizontal) were taken at every corner of these squares and when necessary additional readings were taken at intermediate stations.

The deposit, which is of magnetite, is a contact one, the foot wall being dolomitic limestone and the hanging wall granitic gneiss; between the ore and the hanging and foot walls is a layer of chlorite schist and other green stones.

The dip of the formation is, approximately, between 25° and 40° and is in an easterly direction. The granitic gneiss of the hanging wall rises quite rapidly towards the south, forming a hill. This considerable elevation above the actual deposit tended in some degree to distort the magnetic field.

As will be seen from the map of vertical intensity, the deposit consists of a number of pockets which for convenience of description have been designated in red letters on the map as A, B, C, &c., while the different shafts and pits have been marked Workings Nos. 1, 2, 3, &c.

Starting with the most southerly end of the property surveyed is a pocket which gives promise of containing ore. A pit filled with water and marked Working No. 1 did not admit of investigation as to the quality of ore, dip or other facts which would have been desired. However, according to the magnetic readings, there is still evidence of ore to a workable extent being present here. The blue colour denotes the influence of the upper pole, while the yellow colour denotes the influence of the lower pole.

Situated a short distance to the north of this Working No. 1 is a shaft (Working No. 2), which dips about 30° to the east, the inclination becoming less a little below, and extends for a distance of about 90 feet. This shaft was full of water and could not, therefore, be inspected.

Situated in a northerly direction from the shaft are located the shafts, or Workings 3 and 4, which lie in the area called B. These shafts are part of the principal workings on the property. Shaft or Working No. 3 extends to a depth of about 45 feet, has a dip of about 30° towards the east, and is connected by means of a drift to shaft or Working No. 4, which extends over 300 feet at a dip of about 27° to the east.*

This shaft follows pretty closely the dip of the hanging wall. At about 90 feet from the mouth of this shaft the inclination becomes less. About 10,000 tons of good ore were taken out of this shaft and were piled up along the railroad. This caused the disturbance in the area C.

To the east of Working No. 4 is Working No. 5, an old shaft which has not been used for some time, connected to No. 4 by a drift. To the northwest of Working No. 5

* The thickness of the ore at this shaft is proved by test drill holes to be about 28 feet and the indications are that this is the most promising deposit in this part of the field.

is Working No. 6, a shaft put down by a company some time ago, and from which considerable ore was taken. The blue area D shows the existence of some ore, although not in any workable quantity. The yellow area E is caused by the excavation in Working No. 6. To the northeast of Working No. 6 the deposit pinches out.

The blue area F and its corresponding yellow area denote the existence of a small pocket of magnetite, but cannot be considered worth working.

At area G is a pocket of ore which has to some extent been worked. Working No. 7 is an open cut from which some ore of rather poor quality was taken out. The ore here is mixed with a soft, greenish rock (chlorite schist, epidote, &c.).

Area H is a pocket which is, no doubt, composed of the same class of ore as that at G.

The area denoted by I, J, K forms a deposit which has been broken by the ore taken out from Working No. 9.

Working No. 8 extends vertically to a depth of about 97 feet and has a width on top of about 50 to 60 feet. Both Workings Nos. 8 and 9 were full of water at the time the survey was made and consequently nothing could be definitely ascertained as to the depth of either working. However, from all appearances Working No. 9 seems to extend in an easterly direction and no doubt extends for a short distance under area J. The indications here are good that there is sufficient ore to prove workable.

The area designated by M, N, L and O is caused by the extensive dump which contains a large quantity of good ore. At P is another small pocket which has been worked to a small extent at Working No. 10. But I would not consider this pocket worth working.

Several diamond drill holes have been put down in various parts of the property, but neither the plan of these holes nor the plan of the workings was available at the mine while I was there.

Considerable important information as to the geological features and extent of the deposit might be obtained by the records of the drill cores, &c., and before locating any new holes the plan of the holes already drilled and their direction should be obtained.

The railroad facilities are excellent, since a branch line of the Kingston and Pembroke Railroad runs through the property and a siding also runs along the dumps.

The ore, the analysis of which is given below, is practically self-fluxing. It is also very low in phosphorus and sulphur.

The analysis below is from a sample taken from 30 tons sent to Sault Ste. Marie, and is as follows :—

$Si\ O_2$	6·20	
Fe_2O_3	55·42	Fe=56·69
$Fe\ O$	23·04	
Al_2O_3	2·56	
$Ca\ O$	2·00	
$Mg\ O$	6·84	
$Mn\ O$	0·20	
P	0·01	
S	0·01	

2nd. *Belmont Iron Mine.*—Situated on lot 19, in the first concession of the township of Belmont, county of Peterborough.

The conditions for making a magnetic survey were very favourable, as the terrain was comparatively level, thus permitting of an accurate interpretation of the curves of the map, which would have been more or less distorted had the terrain been uneven or hilly, and the freedom from a thick growth of trees expedited the work considerably.

The work done in the past upon the property consisted of two openings extending in a north and south direction and separated by about three hundred feet. The most southern opening is a pit of about 35 feet in width and fifty feet in length, with a depth of five or six feet. This pit is called the Nichol pit and is so marked on the map.

The largest opening is of irregular shape and has a length of about one hundred and twenty feet in an east and west direction, with a width of about sixty or seventy feet. At the northeast end of this working is a shaft said to be about fifty feet deep, but this could not be verified, nor could an examination of the deeper portions of the workings be made on account of the water which filled all the workings.

The ore which outcropped in several places or was exposed by stripping was of a rusty colour, due to the decomposition of iron pyrites, which could be seen disseminated through the ore taken out some time previously and piled around the workings.

Sand-like material, consisting of magnetite and pyrite, lies on the surface at various points and was at one time experimented with for concentration. The results of a few of these experiments will be given later.

At the time of my visit a New York firm was drilling a hole for the purpose of proving the deposit. A calyx drill was used and appeared to give good results, a core of about one and a half inches in diameter being obtained. This drill hole was put down to a depth of about three hundred feet and I had an opportunity of examining the cores taken out for this depth. The record of this drilling, which was kept by R. Tate, Esq., acting for T. D. Ledyard, Esq., will be given later in this report.

Mr. Ledyard was not satisfied that the drill holes were properly located to prove the property. He, therefore, applied to the Mines Branch of the Department of the Interior to locate a hole. Mr. Nystrom was accordingly sent to Belmont for this purpose, I being engaged at that time in making a magnetic survey of the Wilbur mine.

Mr. Nystrom located a hole on the northern side of the main working which is marked on the map, and the drill was set up over this place, but after drilling through about twenty feet of rock work was stopped.

It was our opinion at the time and this has since been confirmed by an examination of the map of the vertical intensity, that the drill hole put down in this location would have proved the thickness and angle of dip of the deposit, as the dip of the deposit, although very slight, was found to be in a northerly direction.

Before beginning my survey, a base line was laid down in a northeast and southwest direction and cross lines run perpendicular to this line at thirty foot intervals. These cross lines were then divided into thirty-foot spaces, thus dividing the field to be surveyed into thirty-foot squares. The length of the field surveyed was about one thousand feet and the width six hundred feet (three hundred feet either side of the base line).

Readings of both the horizontal and vertical intensity were taken at each corner of every square, with intermediate readings whenever necessary.

Upon the completion of the field work maps were constructed of the vertical and horizontal intensity.

It will be seen upon examining the map of the vertical intensity that the curves are very regular, thus indicating a regular deposit and that the main portion of the deposit lies within the 60° curve, or that portion of the map coloured the darkest. The negative or yellow portion of the map is the attraction of the south pole and indicates by its feeble attraction a considerable depth from the surface of the south pole of the ore body.

The stronger portion of the negative area is caused by the shaft above referred to, which is located at this corner of the main working.

While the area covered by this deposit is comparatively small, the indications are that it extends to a considerable depth and a few holes put down in different places may prove it to be of considerable magnitude.

A great many analyses made of samples from different parts of the field show the phosphorus to be exceedingly low and although the quantity of sulphur existing in the form of iron pyrites is considerable, magnetic separation experiments carried on by different parties have shown that this can be very easily separated out.

The following analyses taken from Professor W. G. Miller's report on this property to the Bureau of Mines, Toronto, January 6, 1905, were made by Mr. A. G. Burrows, Analyst to the Bureau of Mines.

No. 2. Sample taken across a width of 12 feet of the ore body in the southwest corner of the 'Big' pit (main working) :

	Per cent.
Metallic iron	66·74
Sulphur	2·58
Phosphorus	·008

No. 3. Sample taken from ore in place in the Nichol or more southern pit :

	Per cent.
Metallic iron	65·31
Sulphur	·07
Phosphorus	·01

No. 4. Sample from the dump at Nichol pit :

	Per cent.
Metallic iron	59·21
Sulphur	·097
Phosphorus	·01

No. 5. Sample from waste heap to the west of Nichol pit :

	Per cent.
Metallic iron	60·40
Sulphur	·17
Phosphorus	·016

No. 6. Ditto :

	Per cent.
Metallic iron	59·14
Sulphur	·15
Phosphorus	·016

No. 7. Sample selected on account of its high percentage of pyrites, with the object of testing it for gold :

	Per cent.
Metallic iron	58·80
Sulphur	18·18
Phosphorus	·007

No. 8. Ditto :

	Per cent.
Metallic iron	60·96
Sulphur	1·40
Phosphorus	·028

No. 9. North end of main working near shaft. Sample taken from a space 35 x 5 or 6 feet. A little of the surface of the bottom of this pit was covered by water and mud and could not be sampled :

	Per cent.
Metallic iron	55·65
Sulphur	·94
Phosphorus	·02

No. 10. Ditto :

	Per cent.
Metallic iron	55·63
Sulphur	·67
Phosphorus	·018

No. 11. Broken up or sandlike material, consisting of magnetite and pyrite, which lies on the surface of the deposit at various points. Separated by magnetic means, it was found that it gave approximately 89 per cent of magnetic and 11 per cent of non-magnetic material, which contained more or less pyrite. The composition of these two parts of the sample is given in the following analysis :—

Sample marked Magnetite :

	Per cent.
Metallic iron	71·01
Sulphur	0·11
Phosphorus	0·016

Sample marked Pyrite :

	Per cent.
Sulphur	0·70

It will be seen that the metallic iron in the magnetite after concentration is only a little over one per cent below the theoretical or absolutely pure ore.

No. 12. Coarse sample of crude lump magnetite; was crushed to 10-mesh by Professor Kirkpatrick and separated magnetically. The magnetite was found to represent 87 per cent and the pyrite, together with rock matter represented 13 per cent. The composition of these two products is shown in the following :—

Magnetite :

	Per cent.
Metallic iron	67·46
Sulphur	0·129
Phosphorus	0·01

Pyrite :

Sulphur	18·85

The following is taken from the International Separator Company's Report :—

'Ore crushed to between 10 and 20 mesh gave in the concentrate 70·9 per cent of iron and 0·1 per cent sulphur; crushed to 10 mesh it gave in one case 70·9 per cent of iron and 0·1 per cent of sulphur, and in another 71·4 per cent of iron and 0·08 per cent of sulphur.'

The above concentration experiments seem to prove conclusively that the sulphur content of the ore can be reduced to a low enough point to permit of its use in ordinary blast furnace work. (However, the finely divided state of the product would make it undesirable, although it could be used in the blast furnace.)

The best process for treating this ore would be the Gröndal magnetic separation and briquetting process. It may be described in part, as follows :—

The crude ore is reduced to about ½-inch cube in a suitable crusher and then introduced into a Gröndal ball mill, which consists of a horizontal cylinder built up of longitudinal steel ribs with cast-iron end plates, through one of which the ore is introduced together with water, escaping through the other end plate as pulp in a finely ground condition. No screens are required.

The mill is carried on rollers and charged with balls of chilled cast-iron ranging in size from 6 inches diameter downwards. The wear of the balls is said to be on an average about 2 lbs. of metal per ton of ore crushed. The energy required for each mill is from 20 to 25 horse-power, which produces from 50 to 100 tons of ore in twenty-four hours.

This crushed ore is then passed through a magnetic separator. Before charging into the separator proper the pulp from the ball mill is first passed through a slime box, in order to get rid of the bulk of non-magnetic slimes. The pulp now freed from slime passes into a separator proper.

The material after leaving the separator contains just enough moisture to allow of briquetting without the use of any binding material. The briquettes thus made are sufficiently firm to be removed from the press to the trucks used in the furnace, which is long and tunnel-shaped. The furnace is gas-fired, the combustion chamber being situated about the middle of the furnace.

The temperature in the combustion chamber reaches 1,300° or 1,400° C., and is sufficient to agglutinate the particles to form a firm briquette able to stand rough treatment and long transport.

The following analysis was made by Messrs. Pattinson and Stead, of Herräng ore treated by the Gröndal process. (See Journal of the Iron and Steel Institute, No. 1, for 1904.) :

—	Iron. Per cent.	Sulphur. Per cent.	Phosphorus. Per cent.
Crude ore	39·30	1·13	0·006
Concentrates	62·90	0·27	0·003
Refuse	11·40	1·58	0·017
Briquettes	61·10	0·008	0·003
Pig iron from these briquettes	–	0·005	0·012

The location of this property is excellent. It is on a branch of the Central Ontario Railroad and forty-five miles from water navigation at Weller's bay, on Lake Ontario.

A water-power of about 1,000 horse-power, about three miles distant from the mine, has been developed by the Belmont Gold Mine Company, and as it now stands idle power for running machinery, &c., could probably be obtained at a very reasonable figure. Another water-power owned by T. D. Ledyard, Esq., of about 200 or 300 horse-power, lies within easy distance of the mine and could provide ample power for running all machinery. I think the cost of development per horse-power would be quite low.

Note.—According to a letter received recently from T. D. Ledyard, Esq., several new drill holes have been put down in different parts of the deposit, which show good ore at considerable depth.

RECORD of Drill Hole No. 1. Marked on Map of the Vertical Intensity.
Ore fit for Concentration.

No. of Core.	Description of Core.	Depth of Hole.	Depth of Iron Ore drilled through.	Description of Core.	Depth of Hole.	Depth of Ore.
		Ft. In. Ft. In.	Ft. In.		Ft. In. Ft. In.	Ft. In.
1	Good ore..	....	9 0			
2	"	....	5 0	Mixed ore...	....	7 0
3	Fine grained iron...	32 3— 36 0	3 9	....		
	Iron and rock....	36 0— 41 1	2 0	Iron and rock....	36 0— 41 1	3 1
	Good iron...	41 1— 43 3	2 2			
4	"	43 3— 49 5	1 2			
	"	57 0— 62 9	5 9			
5	"	70 0— 74 7	4 7			
6	"	77 0— 82 3	5 3	Iron and rock....	82 3— 82 11	0 8
	"	91 0— 95 4	4 4	Rock with iron.	83 6— 88 9	1 0
7	"	95 4— 95 10	0 6			
	"	95 10— 97 10	2 0			
	"	97 10— 99 3	1 5			
	"	104 2—106 3	2 1			
	Fair iron.....	106 3—110 3	4 0			
8	Iron with rock....	110 3—111 4	1 1	Rock and iron......	115 1—116 2	1 1
8	Iron with rock	119 2—119 8	0 6	Rock with iron.....	117 2—118 1	0 11
	Good iron	119 8—120 7	0 11	" "	120 7—121 2	0 7
	Iron and rock (good).	122 5—128 1	0 8	Iron and rock...	123 1—125 0	1 11
9	" good.........	128 0—133 6	5 6	Rock with iron.......	125 0—128 0	3 0
	" and rock...	134 4—135 7	1 3	Iron, quartz, &c.....	133 6—134 4	0 10
	" good	136 5—140 0	3 7	Rock and Iron.	135 7—136 5	0 10
10	" fair...........	140 0—142 7	2 7			
	" and rock.	143 0—145 0	2 0			
	" (good)	146 1—146 7	0 6			
	" and rock.......	150 5—152 2	1 9	Rock and iron with S.	146 7—148 4	0 9
11	" (close grain)....	157 0—162 2	5 2	Iron and rock........	154 0—155 0	1 0
	....	....	..	" "	155 0—157 1	2 1
12	" with rock. ...	179 3—180 3	1 0	" " ..	165 4—166 4	1 0
13	....	....	..	Rock and iron.. ...	180 3—181 11	1 8
	....	....	..	" "	183 6—185 0	1 6
	Iron (little rock)...	194 5—196	1 7	" " ...	185 0—191 1	6 1
	....	....	..	" " ...	191 3—194 5	3 2
14	" ore	200 0—210	10 0	Rock and iron (fine grain).............	196 —200 0	4 0
15	" and rock.....	224 10—225 9	0 11			
16	" "	230 0—231 6	1 6	Rock and iron..	232 9—234 1	1 4
	" "	234 1—236 2	2 1			
	" "	237 5—245 0	7 7	" " ...	245 9—246 10	1 1
17	" " ...	246 10—247 5	0 7			
	" "	248 1—252 4	4 3	Rock and iron with S.	252 4—260 0	7 8
18	" "	260 3—262 10	2 7	" "	260 0—260 3	0 3
	" "	264 0—267 4	3 4	" "	262 10—264 0	1 2
	....	....	..	" "	267 4—270 0	2 8
19	....	....	..	" "	272 10—274 7	1 9
	" "	274 7—276 2	1 7	" "	288 6—290 6	2 0
	Total........	....	115 6	....	....	60 1

3rd. *Lot 7a, Range V, Township of Leeds, Que.*—This survey was made in May, 1905.

A base line was cut out in the approximate direction of the strike and the field divided into thirty-foot squares in the usual manner.

Magnetic measurements of the horizontal and vertical intensities were taken at the corners of every square and at intermediate stations when necessary.

Upon the completion of the field work a sketch map of the isodynamic lines showing the principal part of the deposit was made. From these isodynamic lines the posi-

tion for a drill hole was located, for the purpose of proving the depth and thickness of the ore, but no drilling up to the present time has been done.

A preliminary report of this survey was published in the Annual Report of the Superintendent of Mines for 1906.

The ore which is magnetite occurs in schistose rock and serpentine, and in places is exposed by outcrops and in others by stripping which was done some time previous to my visit. The strike of the formation is very nearly northwest—southwest, and the dip is approximately 45°-50° to the northwest at the surface.

Some ore had been removed from these exposures and from a test pit (No. 1) shown on the map of the vertical intensity accompanying this report, but the amount removed was so small that the general readings would have remained the same had this ore been left in place.

It will be seen, on examination of the map, that the ore occurs in pockets. These pockets, to facilitate reference, are designated by the capital letters A, B, C, D and E printed on the map.

The positive areas A, B, C and D indicate the existence of ore in the form of pockets, but the indications of the amount of ore present are not sufficiently encouraging to warrant any outlay for development.

The positive area E is the most promising of these pockets and the only one where further prospecting would prove of any value, but even here the indications of the amount of ore present do not warrant any great expenditure.

It will be noted that the positive vertical intensity decreases rapidly in the direction of the dip of the formation. This may be taken as an indication that the ore body has little extension in depth.

A drill hole put down in the position previously mentioned would have pierced the ore body at a depth of 150 feet, if the dip at the surface continued to this depth. If ore does not extend to this depth the deposit is not worth working.

The ore formation continues into the next lot, which is lot 7*b*, range V, but, according to your instructions, I confined my survey to lot 7*a*.

About one day was spent in taking measurements on lots 1 and 3, range X, but no indications of iron ore other than several surface boulders were found.

The nearest railroad station is Robertson on the Quebec Central Railway, about twelve miles drive from this property.

The following analyses were made by Mr. M. F. Connor from samples taken from two outcrops and the test pit mentioned above :

	No. 1. Test Pit.	No. 2.	No. 3.
SiO_2	10·00	8·77	40·43
Al_2O_3	3·70	0·30	0·10
TiO_2	0·10	trace.	trace.
FeO	24·60	25·28	17·98
Fe_2O_3	59·05	64·96	40·10
CaO	1·12	0·43	0·40
MgO	0·50	0·03	0·02
P_2O_5	0·69	0·35	0·37
	99·76	100·12	99.40
Fe	60·48	65·15	42·07
S	0·007	0·007	0·03
P	0·307	0·153	0·163

It will be seen from these analyses that the sulphur is very low in all three samples and that the phosphorus is high.

Your obedient servant,

B. F HAANEL.

ELECTRIC SMELTING EXPERIMENTS.

On account of the great importance of this subject for the utilization of the numerous water-powers and iron ore deposits in Canada, especially in those provinces where coal for coking purposes or coke needs to be imported, an appropriation was made to defray the expenses of erecting an experimental plant for the determination of the following important points referring to Canadian conditions :—

1. Can magnetite, which is our chief ore and which is to some extent a conductor of electricity, be successfully and economically smelted by the electric process ?

2nd. Can iron ores with comparatively high sulphur content, but not containing manganese, be made into pig iron of marketable composition ?

3. Can the electric process be so modified that charcoal, which can be cheaply made from mill refuse and other sources of wood supply, useless for other purposes, could be substituted for coke ? This is especially important since charcoal and peat coke constitute home products.

The Lake Superior Corporation offered, if the plant were erected at the works in Sault Ste. Marie, to furnish the required electric energy free of expense for four months and to place at our disposal their well equipped laboratory and facilities for crushing and briquetting at a reasonable rental. It was deemed that these advantages could not be secured elsewhere and the offer was, therefore, accepted.

Mr. Erik Nystrom, M.E., member of the staff of the Mines Branch, was detailed to proceed to Sault Ste. Marie to superintend the erection of the furnace, which had been designed for the experiments by Dr. P. Heroult, and to make all needed preparations for the commencement of the experiments at an early date.

The difficulty of obtaining the necessary electric appliances and measuring instruments and the fact that the electrodes required to be imported from Sweden greatly delayed the beginning of the experiments.

The official experiments were commenced about the middle of January, 1906, and continued, with a few intermissions for repairs, night and day until March 4.

The experiments were carried out under the directions of Dr. P. Heroult and myself. The working of the furnace, divided into three eight-hour shifts, was superintended in rotation by Messrs. E. Nystrom and B. F. Haanel (members of the staff of the Mines Branch), and by Messrs. R. Turnbull and J. Sejournet (engineers for Dr. Heroult), each being responsible for the respective shifts, notes and measurements made.

A preliminary report of these experiments was published in June, giving the principal results obtained and a full report is at present being prepared for the press.

At the request of the Faraday Society of England a paper on the subject of the government electric smelting experiments at Sault Ste. Marie was prepared by me, which was read on July 2.

A similar paper on the same subject was, at the request of the Chemical Society of the United States, read by me on June 30, at the meeting of the Society at Ithaca, N.Y.

Previous to this an address on the subject was also given by me before the Canadian Club of Toronto on March 12.

Permission was asked by the secretary of the Franklin Institute of Philadelphia, Pa., to reproduce the report in their transactions, which was granted.

After the conclusion of the experiments, the plant was sold to the Lake Superior corporation and the furnace has since March been employed by this company for the manufacture of ferro-nickel pig.

RESULTS OBTAINED BY THE LAKE SUPERIOR CORPORATION.

Mr. E. A. Sjöstedt, Chief Metallurgist of the Lake Superior Power Company, who has had charge of the smelting operations, reports regarding the production of ferro-nickel pig, as follows :—

'During the first few weeks of our experiments minor changes in the shape of the furnace were made, also in the electrode holder, the lime charges were purposely kept low (from 15 to 18 per cent of the ore charge) in order to observe the influence and efficiency of the lime in the elimination of the sulphur and silicon. During this time the furnace product averaged 2,700 lbs. per diem of ferro-nickel with 0·01 per cent S and Si contents, varying from 5 to 11 per cent.

Returning to our old practice and running on 50 per cent lime charge, the product decreased somewhat (yielding from April 4 to May 5 on an average 2,456 lbs. per diem), but the Si contents were reduced to about 3 per cent. The further increase of the lime charge tended to further decrease the Si contents, but at the sacrifice of the production. Finally we settled down to an ore charge of 400 lbs. of briquettes (carrying from 1·5 to 2·25 per cent S), 140 to 150 lbs. limestone of the composition given below and about 120 lbs. charcoal.

Limestone.

	Per cent.
$Si\,O_2$	1·71
$Fe\,_2O_3 + Al\,_2O_3$	0·81
$Ca\,CO_3$	92·85
$Mg\,CO_3$	4·40
P	0·004
S	0·052
	99·826

Up to August 1 about 168 short tons of ferro-nickel had thus been produced. Omitting the first few weeks and taking into consideration only the four full months, April to July, inclusive, during which time the furnace was in continuous operation, with the exception of such unavoidable interruptions as were caused at the power plant and for the changing of electrodes, the following average results were obtained :—

Total product	154 short tons.
Total working time, 114·8 days of 24 hours.	
Average product per working day	1·3415 short tons.
Mean volts on furnace	38
Mean amperes	4,800
Power factor	0·919
Mean electric horse-power on furnace, approx.	225

Output of ferro-nickel pig per 1,000 E. H. P. days=

$$\frac{1·3415 \times 1,000}{225} = 5·96 \text{ short tons.}$$

During this period the following average amounts of raw material were consumed for the production of one short ton of ferro-nickel pig (of an average composition of about 2·75 per cent Si; 0·01 per cent S; 0·03 per cent P; 4 per cent Ni, and 0·8 per cent Cu) :—

Roasted pyrrhotite (about 2 per cent S content)	2 tons.
Limestone	1,500 lbs.
Charcoal, 60 bushels at 20 lbs.	1,200 "
Electrodes	40 "

Since the publication of the report of the commission appointed to investigate the different electro-thermic processes for the smelting of iron ores and the making of steel in operation in Europe,* the following plants have been erected:—

* Published by the Mines Branch, 1904.

In United States—

By Henry Disston & Sons, at Tacony Works, near Philadelphia, Pa.
Type—Induction furnace, by E. A. Colby.
By the Halcomb Steel Company, Syracuse, N.Y.
Type—The Heroult Steel Furnace.

In Germany—

By the Electro Stahl Gesellschft, at Remscheid, near Cologne.
Type—The Heroult Steel Furnace.
By Deutsche Electrische Stahlwerke, at Plattenberg, Westphalia.
Type—The Gin Steel Furnace.

For the Kjellin Steel Furnace contracts are said to have been made by Krupp, in Essen, Germany, and by Vickers, Sons & Maxim, and J. Pd. W. Baldwin, in England.

Since the issuance of the preliminary report on the experiments made at Sault Ste. Marie, Ont., under government auspices, in the smelting of Canadian iron ores by the electro-thermic process advices have been received at this office from Mr. R. Turnbull, representative of Dr. Heroult, that a contract has been secured for the erection of an electric smelting plant to be in operation in six months at Baird, California. The plant is at first to consist of one 2,000 H. P. Electric Furnace with a guaranteed output of 20 tons of 2,240 lbs. of pig iron per 24 hours. If successful, the plant is at once to be enlarged by the erection of additional furnaces with a capacity of 600 to 800 tons per day.

Mr. Turnbull also informs me that he has practically closed with a firm in Mexico for the erection of an electric smelting plant for the production of pig iron, the plant to be in operation within 12 months.

Professor E. G. von Odelstierna in a paper read before the Fjärde Allmänna Svenska Tekniker Mötet,* in Norrköping, Sweden, and published in the Teknisk Tidskrift, No. 30, for the year 1906, comments as follows regarding the consequences of the electric smelting experiments made at Sault Ste. Marie under government auspices:

'The iron industry of Canada in certain ways resembles that of Sweden, viz. :

'1st. The largest number of the iron ore deposits are magnetites, very similar to certain of our Swedish ores, as shown at the Chicago Exhibition in 1893, where we Swedish jurymen, with somewhat painful feelings, studied the Canadian iron ore exhibit. The exhibit consisted of only small samples but from 70 different localities from all parts of the country. The specimens exhibited were mostly rich crystalline magnetites.

'2nd. The large deposits of magnetite seem in general to be located at great distances from the coal deposits, but in localities where abundance of good wood for charcoal is available.

'3rd. Canada possesses in these localities large water-powers.

'There is no doubt in my mind that Canada will develop in the near future a large iron industry, as already stated in my report on the exhibition in Chicago, and whatever doubt there was is now entirely removed when witnessing the energetic steps taken by the government of Canada in later years to reach this aim.

'I require, therefore, now to add that this expansion of the iron industry of Canada will very soon be reached to judge from the results obtained with the electric smelting process,** with which very gratifying results have lately been obtained.

'We have, therefore, to fear that the iron industry of Sweden can expect a dangerous competition from Canada, which not only can cut our market in United States of America, but also our market in England, if that country should adopt the proposed customs union with the colonies; also in regard to China and Japan, is Canada better situated, which is evident from a look on the map.

---

* General meeting of Technical Congress.
** At Sault Ste. Marie, Ont.

'Only in one respect, viz., the cost of labour, are we better situated than Canada, if this is to be considered as a better situation.

'The Canadian government, which already saw the importance for the country of utilizing and smelting their rich ore deposits in the country and not only export the ore, has unconsciously given our government a sharp lesson. As already known, this patriotic government appointed a commission to investigate all the inventions made in Europe for the reduction of iron ores and the making of steel by the electric processes and enabled the commission to publish a standard work on this subject.

'On account of these investigations, it was considered to be of advantage of further experimenting with Canadian raw material in Canada, and the first process employed was the one invented by Heroult. The figures hereafter given are those obtained with this method and lately published in a report by the Superintendent of mines.

* * * * * * * * *

'So much can be said, however, that very important experiments have been made, and even if the greater part of our labour should be continued in the direction of direct producing steel from the ore, a very important part of the practical electro-metallurgy has been solved by the Canadian government and the energetic members of the commission.'

INVESTIGATION OF THE ZINC RESOURCES OF BRITISH COLUMBIA.

It has for a long time been known that zinc ores occurred in British Columbia associated with silver bearing lead ores. The zinc ore until very recently was, however, considered of little value and in most cases was thrown on the dumps. Lately several companies have reconstructed their plants with a view of saving the zinc concentrates as a valuable by-product. These zinc concentrates were in most cases exported to zinc smelters in the United States.

In view of these facts the Silver-lead Association and Associated Boards of Trade of British Columbia petitioned that a commission be appointed to investigate and report on the zinc ore resources and the zinc industry of British Columbia. I was directed by you to prepare a memorandum on this subject, outlining the work to be done and presenting names for your approval of the staff who were to be entrusted with this examination. On approval of this memorandum, Mr. Walter Renton Ingalls, editor of *The Engineering and Mining Journal*, New York city, and author of an extensive work on the 'Metallurgy of Zinc' and a treatise on the 'Occurrence and Distribution of Zinc Ores,' the commercial and technical conditions affecting the production of spelter, &c., was appointed chief of staff of the Zinc Commission.

The following is an extract from the instructions given to Mr. Ingalls regarding the work to be covered and the appointment of his assistants :—

'The examination is to cover—

'1st. Examination of the present development of the mines to determine approximately the tonnage of zinc ore immediately available, its occurence and character and the future prospects, together with the cost of mining.

'2nd. Examination of the present methods of milling.

'3rd. Investigation of the adaptability of the ores to the new methods of concentration (magnetic, electrostatic, &c.).

'4th. Study of the conditions affecting marketing of the concentrate, including the question of smelting in the province or elsewhere in Canada.

'5th. Investigation of the possibility of special utilization of the zinc ore of high silver content.

'Mr. Philip Argall, M.E., of Denver, Colorado, and Mr. A. C. Gardé, of Nelson, B.C., will act as your assistants, the former taking charge of the field work, the latter acting as Mr. Argall's assistant. These parties are to report to you the results of their investigations made in accordance with full instructions to them from you.

'Your recommendation that the investigation of the adaptability of the ores of British Columbia to magnetic and electrostatic concentration, &c., be undertaken by Henry E. Wood, of Denver, Colorado, is hereby accepted.

'Upon the completion of the field work, or sooner if advisable, you are directed to make a tour of the zinc districts of British Columbia to obtain such personal view of the economic conditions as will enable you to form a sound judgment regarding the establishment of zinc smelters, fuel supply and strategical railway locations and such other data as are necessary to arrive at proper conclusions affecting the development of the zinc industry of British Columbia.

'Your report dealing with the economic features of the inquiry is to contain an analysis and summary of the data collected under your direction by your assistants in the field and in the concentration laboratory. The individual reports of Messrs. Argall, Gardé and Wood are to appear in the full report.'

The investigation of certain undeveloped deposits and prospects was assigned to Dr. A. E. Barlow, assisted by Mr. Keele, who were for this purpose detached from the Geological Survey Department.

A report from the Gold Commissioners on zinc ore occurrences in their districts was also obtained through the courtesy of the Honourable the Minister of Mines of British Columbia.

Regarding the erection of a zinc smelter at Frank, Alberta, Mr. Ingalls reports in *The Engineering and Mining Journal,* of July 7, Vol. 82, No. 1, page 22 :

'An interesting innovation in the metallurgical industry of Canada was the beginning of operations by the Canadian Metal Company, which has erected an expensive zinc smelting plant at Frank, Alberta, the purpose of which is to treat the zinc ores of British Columbia, especially of the Slocan district. The plant was located at Frank, on the Crow's Nest branch of the Canadian Pacific Railway, because coal is cheaply available at that point. The company, indeed, owns a coal mine, operated through an adit, the cars of which dump the fuel directly into the bunkers of the gas producers. The plant was put in operation on May 31 and on June 3 spelter was drawn from the condensers of the distillation furnaces, this being the first spelter ever produced on a commercial scale in Canada.'

The report of the commission is at present in the hands of the printer and will be ready for distribution at an early date.

OFFICE WORK.

Numerous requests were made during the year for information relating to mining and metallurgical matters, the occurrence of economic minerals, the mining laws of Canada, &c. The correspondence is steadily increasing and from January 12 to July 1, 1906, 1,821 letters were received.

In addition to the work necessitated in answering these requests much time was consumed in the editing and proof-reading of the different reports issued and the drawing of necessary diagrams and illustrations.

From the City Trade Branch of London, England, and other similar associations several requests have been received for information in regard to mining properties in Canada, with a view of investment of European capital, or exportation to Europe of Canadian minerals.

I am informed by the above association that Messrs. Brandeis, Goldschmidt & Co., 18 and 19 Fenchurch street, London, England, would like to get in touch with Canadian producers, especially of copper, lead and antimony, and that under certain conditions they might be prepared to offer financial assistance.

In view of the numerous inquiries received at this office for information regarding the 'Mineral Industry of Canada,' a publication is urgently needed, which, in addition to the statistics of the mineral production of Canada, would furnish the following information regarding the different mining and metallurgical companies operating in

Canada : Names and addresses of the companies ; date of incorporation; location of their properties; capital invested; names of directors, managers and chief engineers; short description of their works and machinery, and number of workmen employed.

DOMINION OF CANADA ASSAY OFFICE.

During the fiscal year ended June 30, 1906, 21,050·80 ozs. of bullion, valued at $337,820.59, were received and assayed. These deposits were derived from the following sources :—

—	Deposits.	Weights.		Value.
		Before Melt.	After Melt.	
	No.	Oz.	Oz.	$ cts.
Yukon	32	4,357·13	4,265·22	69,388 61
British Columbia	294	15,476·60	15,133·10	245,360 70
Northwest Territories	5	92·65	77·64	2,161 40
Ontario	10	994·97	990·34	18,725 63
Alaska	4	129·45	125·15	2,184 25
	345	21,050·80	20,591·45	337,820 59

	Ounces.
Weight before melting	21,050·80
Weight after melting	20,591·45
Loss by melting	459·35

Loss percentage by melting 2·1821.

The following table shows the business done by the assay office since its establishment:

Fiscal Year.	Deposits.	Weights.	Value.
	No.	Oz.	$ cts.
1901-1902	671	69,925·67	1,153,014 50
1902-1903	509	36,295·69	568,888 19
1903-1904	381	24,516·36	385,152 00
1904-1905	443	29,673·73	462,939 75
1905-1906	345	21,050·83	337,820 59

The following is a statement of difference in value of assays between Seattle Assay Office and Dominion of Canada Assay Office from July 1st, 1905, to June 30, 1906 :

Value bars Seattle assay office	$ 338,909 05
Clippings	702 78
	$ 339,611 83
Value bars and clippings, Dominion of Canada assay office	337,820 59
Extra assay charges	1,111 17
	$ 338,931 76
Total value bars and clippings, Seattle	339,611 83
Total value bars and clippings and extra assay charges, Dominion of Canada Assay Office	338,931 76
Balance in favour of Dominion of Canada Assay Office, Vancouver	680 07

STATEMENT of indebtedness of Government of Canada to Canadian Bank of Commerce for the fiscal year ended June 30, 1906.

Received by Bank.

Extra assay charges	$ 1,111 17	
Difference, Seattle and Vancouver assays	680 07	
		$ 1,791 24

Due to Bank.

Extra assay charges	$ 1,111 17	
Commission on $337,820.59 at 17 cents per $100	574 27	
		1,685 44
		$ 105 80
Jany. 17, 1906.—By cheque from Bank of Commerce, amount due by them on account, purchase of gold to December 31, 1905	$ 35 15	
July 31, 1906.—By draft from Bank of Commerce, amount due by them on account, purchase of gold to June 30, 1906	70 65	
		$ 105 80

Statement of Earnings and Expenditure.

Deposits of gold		$337,820 59
Earnings,—		
Extra assay charges placed to credit of Receiver General	$ 1,111 17	
Value of sweeps and recovery of grains	585 36	
		$ 1,696 53
Expenditure		9,947 24

Percentage of Net Expenses to Deposits, 2·4423.

STATEMENT of extra assay charges received by Dominion of Canada Assay office from July 1, 1905, to June 30, 1906.

From.	To.	Bar Number. From	Bar Number. To	Amount. $ cts.
1905.				
July 1	July 31	1	47	260 33
August 1	August 31	48	86	150 62
September 1	September 30	87	117	114 65
October 1	October 31	118	169	126 79
November 1	November 30	170	206	84 10
December 1	December 31	207	228	49 03
1906.				
January 1	January 31	229	250	57 83
February 1	February 28	251	260	24 00
March 1	March 31	261	282	51 29
April 1	April 30	283	327	66 87
May 1	May 31	328	345	68 03
June 1	June 30			
	Total			1,111 17

STATEMENT of Expenditure made by Dominion of Canada Assay Office, Vancouver, B.C., from July 1, 1905, to June 30, 1906.

Rent	$ 1,200 00
Power and light	114 52
Gas and fixtures	267 99
Chemicals	7 35
Repairs and alterations	50 95
Water taxes	14 40
Postage	9 00
Stationery and printing	3 80
Assayers' materials	69 05
Melters' supplies	42 10
Freight and express	49 49
Telegrams	37 89
Telephone	66 30
Office supplies	35 38
Hardware	40 85
Machinery	642 67
Premium on bond	80 00
Consular certificates	2 50
Thomas McCaffray	2,500 00
J. B. Farquhar	1,500 00
G. Middleton	1,500 00
D. Robinson	900 00
Miss Tierney	720 00
J. O. Sullivan	80 00
T. Fitch	13 00
	$ 9,947 24

The following is a statement of money received and expended by the Dominion of Canada Assay Office, Vancouver, B.C., to June 30, 1906, and shows the unexpended balance of the appropriation to be $1,743.92 :—

Appropriation	$ 11,000 00
Value of sweepings and recovery of grains	580 36
Difference, value, Vancouver and Seattle assays, from July 1, 1905, to June 30, 1906	105 80
Special assay charges	5 00
Total	$ 11,691 16
Expenditure to June 30, 1906	9,947 24
Balance	$ 1,743 92

INVENTORY OF PROOF GOLD AND SILVER ON HAND JUNE 30, 1906.

	Ounces.
Proof gold	6·22
Proof silver	275·65

	Ounces.
Large disks	110·83
Small disks	30·87
Silver bars	133·95
	275·65

CHANGE IN THE CONDUCT OF THE BUSINESS OF THE ASSAY OFFICE.

Hitherto the bullion deposited in the Dominion of Canada Assay Office has been marketed for us by the Canadian Bank of Commerce, the bank receiving for these services 17 cents per $100 to cover marketing expenses. This arrangement has been cancelled by an Order in Council, dated May 10, 1906. The Order in Council provides for the purchase by the government of the bullion deposited, the manager of the assay office being authorized to issue letter of credit cheques for the value of the deposits to the depositors, or if they are unable to present themselves personally to mail cheques to their addresses.

The following regulations regarding deposits and charges thereon have been authorized by the Order in Council of May 10, 1906 :—

1st. Each parcel requiring a separate assay will be treated as a separate deposit.

2nd. All deposits will be treated in the order in which they arrive.

3rd. The gold on which royalty has been paid must be accompanied by a certificate from the Comptroller of the Yukon Territory at Dawson, that the royalty at the rate prescribed by the regulations has been paid.

4th. The charges to be made on each deposit after assays to be as follows :—

On gold on which royalty has been paid :

1st. Charge—Assaying and stamping charge, ⅛ of 1 per cent on the gross value of the gold and silver contained in the deposit.

2nd. Charge—Parting and refining charge : 4 cents per ounce on the weight after melt.

3rd. Charge—Toughening and alloy charge : 2 cents per ounce on 1/11 of the standard weight of gold contained in the deposit.

In paying for silver 1/69 of the stanadrd weight of the gold to be deducted from the gross standard weight of the silver contained in the deposit. This deduction is to cover loss in converting silver from solution.

On gold on which no royalty has been paid an additional charge of one dollar on each melt is to be exacted.

IMPROVEMENTS IN THE INTERNAL ARRANGEMENT OF THE ASSAY OFFICE AND ADDITIONS TO EQUIPMENT.

The upper back windows of the Assay Office, which had so far been left unprotected, have been ordered, for greater safety, to be provided with iron gratings.

Mr. Middleton, chief melter, having reported that the space from the melting furnace table to the partition being only 4 feet 8 inches, sufficient room was not given to handle large melts required by the provisions of the Order in Council which changed the conduct of the business of the Assay Office, it was decided, to avoid accidents, to move 12 feet of the partition opposite the large furnaces in towards the office 2 feet 6 inches, which would make the space between the large furnace table and the partition 7 feet 2 inches.

The assay weights having been in use for four years, it was found that their accuracy could no longer be depended upon. A set of standard weights of 500 oz. down to 1/100 of an ounce, with a certificate of the United States Standardizing Bureau, was, therefore, ordered from Henry Troemner, Philadelphia, Pa. On receipt of these standard weights by the manager of the Assay Office, he was instructed to institute a comparison of the office weights by substitution with the 'standards.' The following is his report thereon :—

DOMINION OF CANADA ASSAY OFFICE,
VANCOUVER, B.C., April 23, 1906.

This certifies that the office weights designated below have been compared by substitution with the 'standards' and the following corrections made, viz.:—

Designation.	Correction.	Distinguishing marks.	Sensibility of balance.
500 oz	*·03/100 oz.	1 dot	100 mgrms.
500 "	*·04/100 "	2 dots	100 "
300 "	None.	.....	100 "
200 "	*·01/100 oz.	1 dot	100 "
200 "	*·01/100 "	1 "	100 "
200 "	*·01 100 "	2 dots	100 "
100 "	None.	.....	100 "
50 "	"	.....	80 "
30 "	"	.....	70 "
20 "	"	.....	70 "
10 "	"	.....	70 "
5 "	"	.....	70 "
2 "	"	.....	70 "
2 "	"	.....	70 "
1 "	"	.....	50 "
½ "	"	.....	50 "
¼ "	"	.....	50 "

A * means that the weight was heavier than the Standard.

The necessity, according to the provisions of Order in Council of May 10, 1906, of melting all small ingots for marketing purposes into large ingots not exceeding 1,400 oz. in weight required the use of an ingot balance. This balance of 2,000 oz. capacity, sensibility 1/1000 oz., with beam encased, and standardized weights to accompany same, was ordered from Henry Troemner and has since been received at the Assay Office.

ADDITIONS TO THE STAFF OF THE ASSAY OFFICE.

On the resignation of Mr. J. Walter Wells, chief assayer, on April 30, 1904, Mr. J. B. Farquhar was appointed chief assayer on July 1, 1904, and the services of an assistant were dispensed with in the interests of economy.

The change in the conduct of the business of the Assay Office constituting it a purchasing office rendered it advisable, to insure the proper checking of the assays, to appoint an assistant. Mr. A. Kaye, who had been in the employ of the Canadian Bank of Commerce at their Atlin branch as assayer during the years 1901, 1902, 1903 and 1904, and whose work in this capacity has been vouched for as satisfactory by Mr. H. H. Morris, Inspector of the Canadian Bank of Commerce, was appointed to this position, his duties to commence July 1, 1906.

APPENDIX.

In the appendix a description is reproduced of the Heskett-Moore iron process, which I owe to the courtesy of the Superintendent of Commercial Agencies, Mr. F. C. T. O'Hara; also a letter received from the manufacturers in England regarding the new explosive 'Ammonal.'

I have the honour to be, sir, your obedient servant,

EUGENE HAANEL,

Superintendent of Mines.

APPENDIX.

Description of the Heskett-Moore Patented Direct and continuous process for Treating Ferruginous Ore for the Manufacture of Iron and Steel, showing the method employed and the commercial advantages arising therefrom.

The process is a method for directly converting iron ore into malleable iron or steel by a continuous system.

This process consists essentially in first reducing iron ore to a fine state of division, and separating the gangue therefrom by electro-magnetic treatment, or other approved method of concentration, leaving a pure oxide of iron, which is then treated automatically by a pure fuel, reduced to a metallic state, and finally fused and delivered from the furnace in the form of malleable (commercially pure) iron and steel as desired, by one direct and continuous process doing away with the intermediate stage of pig iron.

Any iron ore can be treated by this method, but the New Zealand iron sand, in consequence of its natural extreme fineness is particularly adapted for treatment.

In New Zealand enormous deposits of magnetic iron sand exist on the beaches of the west coast, the value of which is clearly recognized, so much so indeed, that the New Zealand government offer to take 65,000 tons of iron smelted from the sand, at English prices with carriage and expenses added, and in addition to give a bonus of £1 per ton for the first 20,000 tons to encourage the establishment of iron works there, conditionally upon a plant of a certain value being erected.

Although many processes have been tried, until now no commercially successful means of treating the sand has been proved.

Owing to the fineness of the sand some inventors who had operated on it conceived the idea that the best way of working it was to mould it into 'briquettes' and smelt them in an ordinary blast furnace, producing pig iron in the usual way. The necessity of making sand into briquettes or the production of pig iron at all, has been obviated by the introduction of this process.

In the present patented process, gaseous fuel free from impurities specially prepared in the apparatus, is used, and is perfectly under control. Instead of making the iron sand into briquettes thus adding to the cost before smelting, and also introducting impurities into the iron during the smelting and adding to the cost of subsequent treatment, the magnetic sand under the new process is treated 'automatically' and without the addition of any fluxing agent.

The trial runs of the plant constructed at South Melbourne have proved conclusively that the method and apparatus designed by the inventors have produced malleable iron and steel direct of a very high quality.

It is estimated by those competent to judge that the highest grade of tool steel can be produced for less than three farthings per pound—or for very little more than the cost by other methods of ordinary grades of steel for structural purposes ; steel rails can be produced for under £4 per ton, and malleable iron for £4 10s.

One of the inventors of the new direct and continuous process, Mr. T. J. Heskett is well versed in English iron smelting methods, having been trained to the business in Middlesborough, England.

After working at Onehunga, New Zealand, on the iron sand, the result, in conjunction with Mr. Montague Moore, was the discovery of the present method of obtaining malleable iron or steel direct from the ore instead of pig iron as hitherto.

The company has obtained a lease of 320 acres at Lal Lal, near Ballarat, upon which there is an extensive and rich deposit of hematite iron ore, and has also arranged for a special concession of beach frontage from the New Zealand government at Manukau Heads, upon which there is a very large deposit of high grade magnetic iron sand sufficient for many years consumption.

The following details explain the mode of working :—

Starting with the iron sand or pulverized iron ore it is dried and separated from its gangue, by which means iron oxide separated from every impurity is obtained. The great natural fineness of the New Zealand iron sand, admits of a thorough separation of the impurities, but in Australia and other countries the ore to be smelted by the new system will first have to be reduced to a fine state of division and concentrated.

After separation, the purified iron oxide is automatically fed into the furnace.

The first portion of that furnace consists of a heating chamber, wherein by using the waste heat from subsequent operations, the iron oxide is thoroughly heated. It then mechanically passes into what is called the reducing chamber, where a jet of gaseous fuel takes up the oxygen from the oxide of iron particles, which are thus converted by deoxidation into particles of metal, which are automatically fed into the melting furnace, and converted into malleable iron or steel according to arrangements made.

The commercial advantages are :

1. By using a pure ore freed from foreign matter by magnetic or other separation, there is no cost for fuel to melt the gangue into slag, and afterwards disposing of that waste product. Also the much greater economy with which the fine atoms can be heated as compared with solid ore in lumps effects a large saving compared with existing methods.

2. Sulphur and phosphorus are usually present in both fuel and fluxes. These elements act injuriously upon iron and steel, and cause much expense in effecting their separation. By using a gaseous fuel alone these impurities are not present, or if present are easily removed before the gas is used for smelting. Also by using a purified ore, the result is the production of a very high class malleable iron or steel. There is also the advantage of having the heating quickly and certainly under control.

3. The arrangement of the furnace utilizes the waste heat, a thorough conversion of it being achieved throughout the whole cycle of operations, which is continuous from the sand to the finished metal.

4. The most important saving is effected by adopting this direct process, and the subsequent diminution of the number of operations necessary. The present commercial process, which the Heskett-Moore invention is intended to supersede, consists first in the production of pig iron, an impure type of metal requiring detailed handling, puddling, bessemerising, &c., before conversion into wrought iron or malleable iron or steel. Working by the Heskett-Moore process with a pure ore free from foreign matter and using as a fuel purified gases, the direct and continuous result is metal at once fitted for use as wrought iron or steel as may be required.

5. The working plant is so arranged that the process, as well as being continuous, and saving any reheating of the metals, as hitherto, is entirely automatic; as after the iron sand is fed into the magnetic separator, the pure oxide taken by mechanical conveyors and fed by them into the heating chamber, and no handling occurs until the malleable iron or steel is produced from the melting furnace, ready to be wrought under the steam hammer, and rolled into rails, plates or bars.

One of the chief impediments to the successful establishment of iron works on a large scale in Australia, has hitherto been the high price of labour as compared with other countries. By the new direct and continuous method of smelting much less manual labour is required than under the older system, and malleable iron or steel can be produced here at less cost than similar qualities of metal under present conditions in England. The invention having been proved at South Melbourne Works by the production of high quality iron and steel, very far reaching consequences will result.

In fact a revolution must be effected in iron and steel manufacture throughout the world, and, recognizing the immense benefits which will accrue, patents have been applied for in New Zealand, Great Britain, Norway, Sweden, France, Belgium, Germany, Russia, Canada, India, the United States of America, the Commonwealth of Australia, Japan and the Transvaal.

The company which has secured the invention intends to run the works at South Melbourne, to demonstrate its value to Australian capitalists able to establish works in the different states of the Commonwealth and also the representatives of ironmasters from other countries.

Excellent cutting tools of the finest quality have been made from some of the steel manufactured, and may be seen at the office of the company.

The cost of erecting a large smelting plant on this system would be less than one-fourth of the cost of a smelting plant on existing methods to produce the same quality of metal.

Finally it may be stated that the directors aim at making large profits for the shareholders, not from establishing works in the different states and countries, but from the sale of the patent rights to those able to finance and establish ironworks on an adequate scale.

THE MOORE-HESKETT STEEL AND WROUGHT IRON FURNACE.

A is the ore feeding-hopper delivering a constant stream of powdered iron ore into revolving cylinder B. The cylinder is lined with fire brick and has projecting shelves for raising the ore. It passes from cylinder B into cylinder C through a small opening in damper L and from there falls into revolving furnace D.

The ore is heated in cylinder B, deoxidized in cylinder C and either balled up for wrought iron or melted for steel in revolving furnace D.

The fuel (in this plant being crude oil) is sprayed into cast-iron retort E under pressure at F, passes through reducing cylinder C then through gas port J into revolving furnace D where it meets the hot air coming in through port I. The heated products of combustion enter the flue H and pass through regenerators G, around retort E and then through revolving cylinder B to chimney.

Cold air enters the regenerator G at N passing through flue N^1 to port I.

The gas and reduced particles of iron enter the furnace through the fire clay pipe J which is protected in front by the furnace lining. The furnace is lined with chrome ore in blocks made roughly in a spiral form so that the ore is gradually worked forward in the furnace and either delivered in the form of puddled ball, or melted for steel, depending upon the temperature maintained.

When the reduced ore falls into the furnace the gas plays over it, effectually preventing any possibility of reoxidation taking place before the finely divided iron particles become absorbed in the bath of metal or slag.

A tapping hole (not shown) is provided in the centre of furnace above the pit.

A small jet of compressed air is found sufficient to urge the air draught at N through regenerators which heat the air by conduction through the firebrick work.

As there is no chemical reaction taking place in the furnace a refractory basic lining should retain its form for a long time and ball its iron up and deliver it direct into a revolving squeezer or when making steel keep moving the iron forward across the bath to facilitate smelting.

In the working plant electro pyrometers are used to aid in maintaining a uniform temperature, and valves (not shown in the outline sketch) are provided for regulating the heat in the various parts of the furnace.

AMMONAL.

A letter of inquiry to the 'Ammonal Explosives, Limited,' of London, England, regarding the applicability of their new explosive 'Ammonal' elicited the following letter of reply :—

29 Great St. Helens,
London, E.C., 2nd August, 1906.

Eugene Haanel, Ph.D.,
Superintendent of Mines,
Department of the Interior,
Ottawa, Ont.

Sir,—Mr. Harry E. Winter, who is now visiting Canada with a view to introducing our Explosive Ammonal, has asked us to write to you on the subject of this explosive and on the various important points in relation to the same.

Ammonal is composed essentially of nitrate of ammonia, charcoal and metallic aluminium, and advantage is taken in this composition of the great heat given off by the aluminium at the moment it forms into aluminium oxide in order to expand the gases formed by the explosive decomposition of the nitrate of ammonia. Thus a great volume of gas is produced, which, owing to its very high temperature, is suddenly expanded. In point of strength the various qualities of ammonal which our company produce range from that of slightly above black powder to the strength of blasting gelatine, according to the quantity of aluminium that is added, but of course there is a point above which the percentage of aluminium cannot go and that is arrived at by working out the chemical equation. The outstanding feature of this explosive is its great strength and safety. As far as the former is concerned the trials which have been carried out in Canada are ample proof and as to safety any one interested in the subject can with perfect impunity carry out any sort of trial he pleases. The explosive will not freeze and does, therefore, not require thawing. It has sprung into favour in this country ever since it has been introduced, and we are now selling large and constantly increasing quantities.

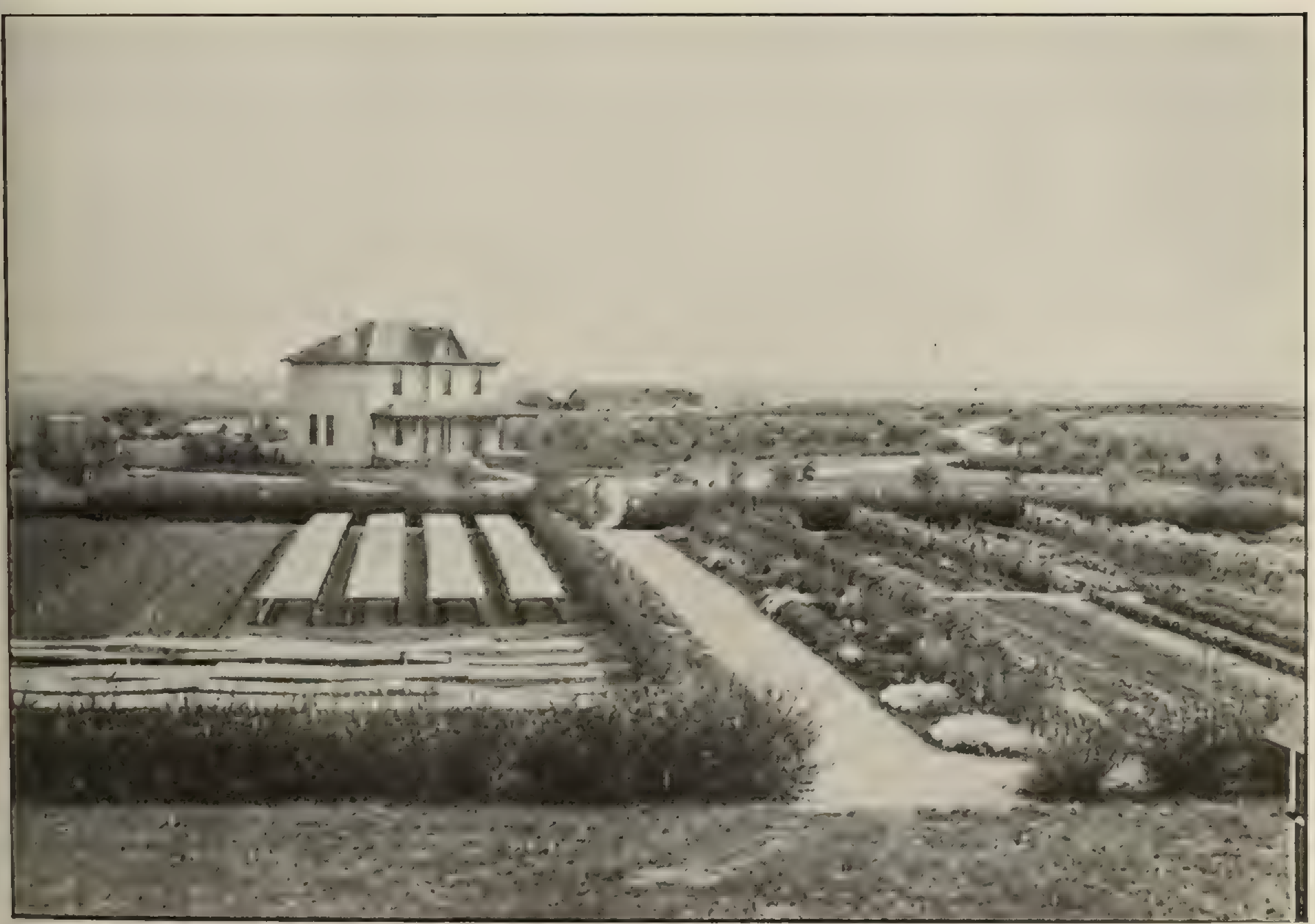
Mr. Winter has no doubt been able to show you all, or at least some, of the reports we have on the actual work of the explosive, and we may only add that for military purposes it has enjoyed great favour on the continent, as several powers have adopted it for shell filling, and the English government has also now got the question under consideration. Needless to say, His Majesty's inspectors of explosives have licensed ammonal for use in fiery and dangerous mines and for general purposes. We would suggest that if the matter is of sufficient interest to you you should request Mr. Winter to carry out a special series of experiments so as to prove to you the correctness of our statements.

We are, sir,
Yours respectfully,
(Signed) AMMONAL EXPLOSIVES, LIMITED.

Forests in the Crowsnest Pass.

Effect of a forest fire in the Crows Nest Pass.

25—viii—4½



Forest Nursery Station, Indian Head, after three years of cultivation.

Black Spruce 80 years old, too crowded to grow well.

White Spruce 28 inches in diameter growing mixed with poplar.

Riding Mountain Forest Reserve.

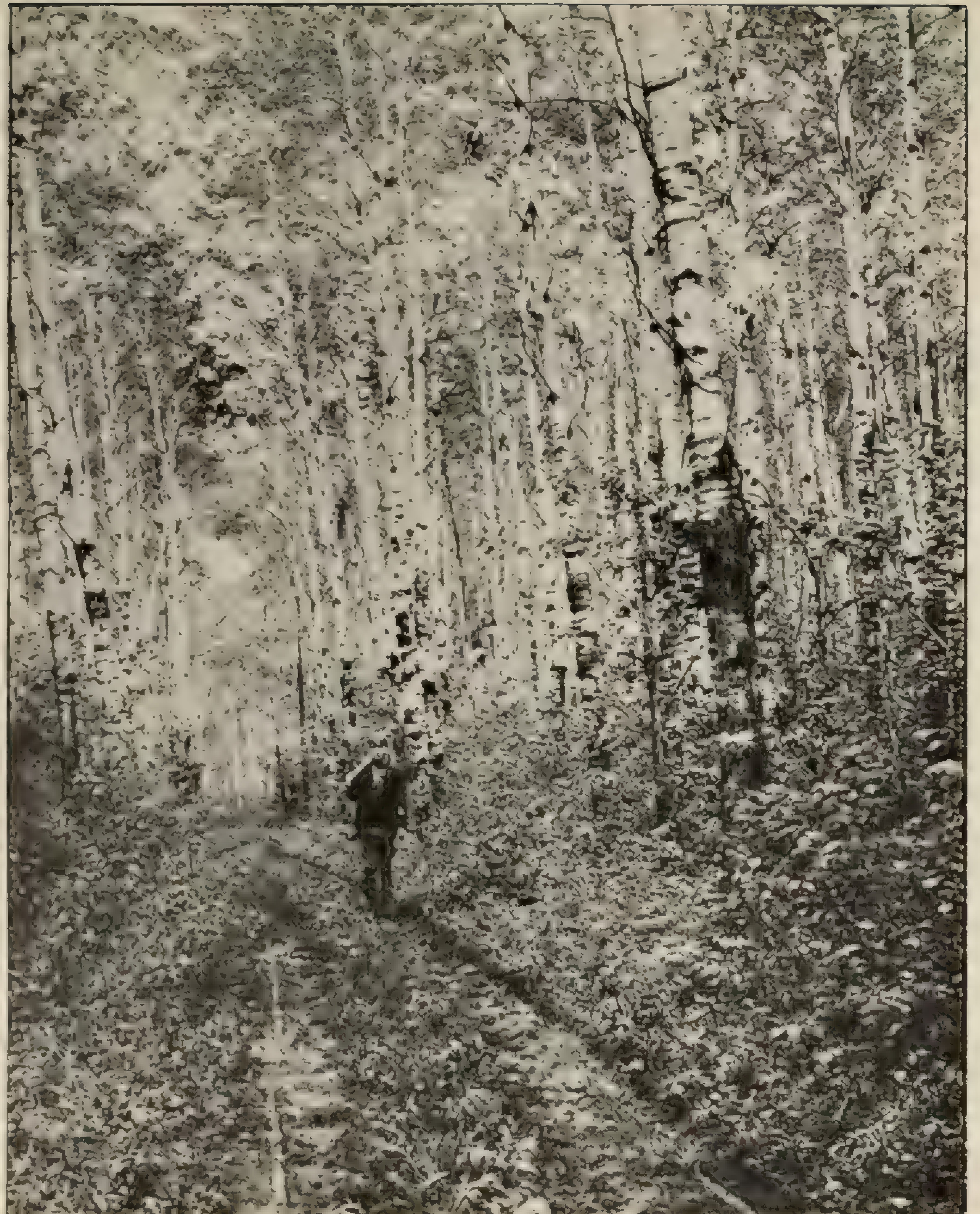
Aspen and Balm reproduction in the Cooking Lake Forest Reserve.

J. & T. Shaw's Mill in the Riding Mountain Forest Reserve.

REPRODUCTION OF THE MOOSE MOUNTAIN FOREST RESERVE AFTER THE FIRE OF 1897.

Twenty year old reproduction of Aspen and Balm of Gilead in the Moose Mountain Forest Reserve.

Measuring the rate of growth of Aspen in the Turtle Mountain Forest Reserve.



ASPEN FORESTS IN THE RIDING MOUNTAIN FOREST RESERVE.

PART IX.

FORESTRY.

REPORT OF THE SUPERINTENDENT OF FORESTRY.

DEPARTMENT OF THE INTERIOR, FORESTRY BRANCH,
OTTAWA, September 17, 1906.

W. W. CORY, Esq.,
Deputy Minister of the Interior,
Ottawa.

SIR,—I have the honour to submit the eighth annual report on forestry, accompanied by the reports of the Assistant Superintendent, the Inspector of Forest Reserves and other officials connected with this service.

At the last session of parliament, an Act respecting forest reserves was passed which places the management of them under this branch of the department. It is to be hoped that this is only a commencement and that all timbered land which is unsuited for agriculture or grazing purposes and which is suited for growth of timber will be in time permanently set aside for that purpose.

The Act also provides that the fish and game within these reserves shall be looked after by this branch.

As has been stated in previous reports, the two cardinal points that have been constantly kept in view since the organization of this branch have been *conservation* and *propagation*. Heretofore propagation has been principally confined to tree planting on the plains, which will be dealt with later on, but two years ago a small commencement was made in the planting of coniferous seedlings on the sandhills in the Spruce Woods reserve east of Brandon.

The first year's planting, consisting of about 10,000, was as an experiment and the result was such as to encourage further efforts in this direction, and in 1905, some 13,000 Scotch pine were planted. The percentage of loss in this case was comparatively small ; and as will be seen from the report of the Assistant Superintendent herewith, some seventeen thousand were planted this season, of which practically all are now living.

As the land in question is useless for any other purpose, I think it would be wise to greatly increase this work in the future.

By referring to Mr. Craig's report, it will be seen that the work of forest surveying begun last year on the reserves in the Turtle and Moose mountains, is being continued this year in the Riding mountains.

REASONS FOR ESTABLISHING FOREST RESERVES.

As the object aimed at by the department in setting aside certain areas of land for forest reserves seems to be frequently misunderstood, a few words on the subject may not be out of place.

It will be seen by reference to the map that most of the reserves so far set aside have been on land unsuited for agriculture but which will produce timber. In many cases this is owing to the high altitude ; in other cases, such as in that of the Spruce Woods reserve, the soil is so poor that agriculture crops cannot be succesfully grown on it. But the most important consideration that has impelled the department to take up this matter is in order to conserve water supply.

It is not too much to say that the future of the prairie regions for the growing of grain will be greatly jeopardized if the water level in the soil is decreased, and this result will certainly follow if the natural reservoirs at the sources of supply in the

hills are destroyed, as they would be if the timber thereon were removed. So important is this that even if the land in such reserves only served this simple purpose, it would be wise to keep it in forest. But while serving this purpose it is the aim of the department to utilize the land for the production of timber and to so harvest the timber crop that a permanent supply may be continuously maintained, and in order to direct what may be cut, and to what extent, a careful examination or forest survey is necessary.

Permit me to emphasize what I have said in other reports, that the products of these forests and all others on public lands are for the use of the public, and the object aimed at is to administer them so that their highest use, not only for the present, but future generations may be secured.

In any forest there will be found a certain proportion of diseased trees which are injurious. These trees are frequently valuable to the settlers for the timber they contain and they will be encouraged to remove them.

The examination of the Turtle Mountains reserve, showed also that there were 63,710 cords of dead and down timber useful for fuel and which should be removed.

This survey also shows the quantity of growing timber, its size and rate of growth, which enables us to say what quantity can be cut each year without impairing capital, or in other words, without decreasing the annual future supply.

FIRE GUARDING.

The work of protecting the timber from destruction by fire has been continued this season with good results. The only serious destruction reported so far is from a fire that occurred in April at the upper waters of the Red Deer river, in Alberta, which is referred to in Mr. Stauffer's report.

The early part of the season was very dry in the prairie provinces, and the rangers were kept very busy fighting fires, and there is no question that notwithstanding the loss of valuable timber above referred to, the destruction would have been many times greater, taking the country as a whole, if no such service had been in force.

In the railway belt in British Columbia the rangers have been kept busy during the whole summer. Up to the early part of September the weather had been exceedingly dry, and fires were numerous throughout the district. In some cases the rangers were compelled to engage additional assistance and to work day and night for weeks to keep the fires from spreading into valuable timber. It is very gratifying to know that the amount of merchantable standing timber that has been lost has been very trifling, and as there have been heavy rains recently, it is not probable that there will be so much difficulty in the work of protection from now on till the close of the season.

TREE PLANTING ON THE PRAIRIES.

The report of the Assistant Superintendent on tree planting on the homes of settlers, deals very fully with that branch of the work. Some 7,000,000 trees have now been supplied by the department to those who have had their land properly prepared. The reports of all of the inspectors for this year have not yet been received, but as the season has been a very favourable one, it is expected that these reports will be quite as gratifying as those for any year since the work was started.

The applications so far, from settlers desiring to avail themselves of the co-operation of the department in this regard, are more numerous than they have been up to the present date in any year since the work was begun.

The trees set out in former years under this scheme are now beginning to attain such a height as to be visible for long distances across the prairie, and to furnish the much needed shelter so desirable on a prairie farm.

FOREST NURSERY STATION.

From the commencement of the scheme which involved the furnishing of seedling trees to the settlers, this branch has been indebted to the Department of Agriculture for the use of land on the experimental farms for the growing of this stock. As the applications increased, our requirements became too large to be provided by them without interfering with their own work, and a commencement was made a few years ago on a new prairie section about a mile and a half southwest of Indian Head. As this land had to be brought into a suitable state of cultivation before it was fit for nursery purposes, we have been compelled to use the land at the experimental farms to a greater or less extent up to the present time.

The work at the Brandon experimental farm ceased with the crop of 1904, and after the present season we will be able also to discontinue the use of the land that we have occupied for several years at the Indian Head farm, and centralize the whole work at the nursery station, and in this connection I desire to bear testimony to the assistance that the Department of Agriculture has rendered this branch. The minister, the director of experimental farms and the superintendents at Indian Head and Brandon have from the start of our forestry work shown a most kindly spirit and have aided very much in the success that has attended it. The nursery station in addition to furnishing several million trees for annual distribution, which is the main object of its existence, will also, through the permanent plantations of various varieties of trees thereon, afford reliable data as to the rate of growth of each variety, and other information which is much needed by the sylviculturist in those regions.

With a view of obtaining some knowledge of the forestal conditions of our far northern districts, I have just concluded a long journey down the Mackenzie river waters as far as Fort McPherson, near the Arctic Sea, returning by way of the Porcupine and Yukon rivers. A report in detail of this interesting trip would be too lengthy to insert here. I may say, however, that in the basins of the Athabaska, the Peace, the Liard and other tributaries of the Mackenzie, as well as the valley of that great river itself, are contained vast quantities of timber. The spruce, white and black poplar, birch, tamarac and jack pine are the principal varieties, the spruce being by all odds the most valuable. Though it was impossible for me to see but a very small area of the timbered territory, there can be no question that these northern regions contain a very great quantity of spruce timber, large enough for lumber and a practically unlimited supply of pulp wood material.

CANADIAN FORESTRY ASSOCIATION.

This association which has done so much to awaken public interest throughout the Dominion, continues to increase its membership, which now numbers about 1,500.

In the month of January last, a great forestry convention was held at Ottawa, at the call of the Premier, the Rt. Hon. Sir Wilfrid Laurier, and under the auspices of the association. This meeting, which lasted four days, was opened by His Excellency the Governor General and presided over by the Premier, and was by all odds the most important gathering of the kind ever held in Canada, and has contributed to further arouse public attention in our great forests and the forestry problem in general.

The association was invited by Nova Scotia and also by the lumbermen of British Columbia to hold a summer session in those provinces respectively. The executive decided to accept the invitation of the latter this season, and such a meeting will take place at Vancouver on the 25th, 26th and 27th of this month. It is called by the Lieutenant Governor of the province, and promises to be a very large and influential gathering.

Your obedient servant,

E. STEWART,

Superintendent of Forestry.

APPENDIX No. 1.

REPORT OF NORMAN M. ROSS, B.S.A., B.F., ASSISTANT SUPERINTENDENT OF FORESTRY.

INDIAN HEAD, SASK., June 26, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour to submit my sixth annual report of work carried out under your instructions, dating from August 19, 1905.

From August till December 15 I remained at the nursery station here looking after the sowing of seed, cultivation, digging and heeling in of seedlings and other necessary work. From December 20 to January 29 was spent in the office at Ottawa. On the latter date I returned to Indian Head.

On the whole the past season has been particularly favourable for tree growth, and the success of the plantations already set out under our co-operative system has done much to stimulate the general interest in tree planting which is demonstrated by the greatly increased number of applications from settlers wishing to avail themselves of our present system of planting. That there is far more activity along this line of work than there was a few years ago is shown too in the evident increase in the commercial nursery business. All the western nurseries seem to be enlarging their operations and some new companies with considerable capital have been established this year.

When the co-operative scheme was first put in force it was looked upon with considerable disfavour by the western nurserymen, as they maintained that it would affect their business unfavourably. In some instances considerable opposition was manifested. The greatly increased demand for nursery stock of late years has, however, conclusively shown that if anything the present system is of great benefit to the nurserymen, and as time goes on it will undoubtedly be found that it would almost have been impossible to undertake any work which could prove so beneficial to the nursery trade. The distribution from our nurseries is limited at present to four or five varieties, namely, native maple, ash, elm, Dakota cottonwood and willow. These are sent out only as small seedlings and according to agreement must be set out in block form or as shelter for gardens and buildings. It will be seen that in reality this encroaches but slightly on the regular nursery trade which chiefly supplies stock for ornamental planting, such as shrubs, or larger trees for avenue planting, fruit trees and bushes and perennial plants. It has now been fully demonstrated that without shelter it is not possible to grow many kinds of fruit and ornamental shrubs and that the value of the ordinary vegetable crops and hardy fruits, such as currants and raspberries, is increased at least fifty per cent when protected by suitable shelter belts. As every settler is extremely anxious to grow fruit and vegetables and to beautify his surroundings, it will be readily seen that wherever a plantation has been set out under our co-operative system the owner is practically certain to purchase nursery stock for planting on his sheltered grounds.

It is also very easily seen that in a few years the Forestry Branch will not be able to supply even a small proportion of the demand for forest seedlings which is bound to increase very rapidly. With present facilities our annual stock for distribution cannot exceed four million seedlings, which number is almost insignificant when we consider the immense territory over which they are distributed. There would be a very good market for seedlings of hardy native trees for shelter purposes provided

nurserymen grew them on a sufficiently extensive scale to permit of their being sold at a price which the ordinary farmer can afford. One year old maple and two year old ash seedlings can be grown at a very good profit if sold at from $3 to $4 per thousand. There seems to be a very great demand for evergreen trees, but up to the present there is only one nursery in the west where this class of stock has been grown from seed. The native spruce, native jack pine and the Scotch pine are very easily raised from seed. The native tamarac is another conifer which gives evidence of being particularly adapted to prairie planting. The raising of hardy coniferous seedlings is a work which western nurserymen would find extremely profitable, as the demand for this class of stock is practically unlimited.

Since the spring of 1901 over 7,000,000 seedlings have been distributed throughout Manitoba, Saskatchewan and Alberta. The reports sent in by the various inspectors in regard to the different plantations inspected by them are very encouraging. In one or two instances trees have been neglected, but such cases are the exception. The great majority of the plantations are in excellent condition, the reports showing that at least 85 per cent of all seedlings sent out are now living. The inspectors all report a greatly increased interest in tree planting both in the towns and country districts.

This year so far we have not received any reports, as the inspectors have only been out a few weeks. But as the season has been such an extremely favourable one, it is safe to assume that the percentage of trees set out this spring which are still alive is as high as in former years.

This spring the lists sent up from Ottawa showed 1,500 applicants in Manitoba as against 1,400 last year, and somewhat over 2,200 in Saskatchewan and Alberta as against 1,500 last season.

The inspection in Manitoba is being done by Messrs. A. P. Stevenson, A. H. D. Ross and F. W. Jacombe; in Saskatchewan by Messrs. John Caldwell and Angus Mackintosh, and in Alberta by Mr. C. Brandt. Owing to the number of new branch lines constructed during the past season and the rapidly increasing settlement, the ground which the inspectors have to cover is considerably more extended than formerly. Consequently it will be necessary to add to the staff if it is desired to continue an efficient service. The value of the inspection can hardly be overestimated, and it is practically safe to say that without it the distribution of large numbers of seedlings would be of little use. The necessity for properly preparing the ground before planting is now generally admitted, the inspectors reporting that the percentage of applicants who do not have their ground in suitable shape is decreasing each season.

PLANTING OF SCOTCH PINE IN SPRUCE WOODS RESERVE.

On the 15th May we commenced setting out an additional 17,000 two-year old Scotch pine seedlings alongside of the planting done last spring. The seedlings were set in the same manner as last season, namely, furrows four feet apart, running east and west were drawn out in the sod, and the seedlings placed in the bottom of the furrows close to the land side in order to shade them as much as possible from the sun. The soil was in splendid condition, being quite moist. Since planting there has been abundance of rain, so that the young plantation has had exceptionally good chances.

The planting of last season is extremely encouraging. After a very careful count I estimate that from 88 to 89 per cent of the young plants are alive now and should this season make a growth of six or more inches.

The two-year old plants set out in 1904, and which were alive in spring of 1905, last year made a good growth though the sod had again covered the small spots which had been dug when they were planted.

The soil where the planting was done is almost pure sand, the grass not forming such a thick sod as is found on the richer lands. It is possible that this method of planting might give good results on richer soils, but only when conifers are used. However, we would not recommend this method to the settler, as the growth would be

so extremely slow that it would be years before the trees could be of any value for shelter.

It is probable that in the future the planting operations on this reserve will be considerably increased. The lands at present are valueless, being unfit for agriculture and affording scarcely any pasturage for stock. The only use to which they can be profitably turned is the raising of wood and timber. At present there are scattered over the reserve isolated white spruce trees, some of which are very old. These will greatly aid in reforesting this tract as they produce a considerable quantity of seed. It is essential, however, to keep out the prairie fires, as the young seedlings starting in the grass are very easily destroyed.

EXHIBITS.

This season it is proposed to make a forestry exhibit at the Winnipeg Industrial Fair and also at the Brandon Fair. This exhibit will consist chiefly, as in former seasons, of specimens of native grown timber, wood grown under cultivation, boxes and pots of growing seedlings suitable for prairie planting, samples of tree seeds, pressed leaves, photographs, &c.

During recent fairs the forestry exhibit has caused considerable interest and undoubtedly does much towards the encouragement of tree planting in the west.

NURSERY WORK.

Last fall the digging of the stock for distribution commenced on the 27th of September.

The following numbers were tied up and heeled in for winter :—

Maple	1,246,000
Ash	600,500
Elm	7,625
	1,854,125
Cottonwood	150,000
	2,004,125

The cottonwoods were imported from North Dakota. All these seedlings were distributed this spring and with the addition of about 30,000 willow cuttings, brings this year's distribution up to 2,034,125.

Besides the seedlings about 200 pounds of ash seed was sent out. Last year it was difficult to obtain the maple seed. We were only able to get sufficient for our own planting. Consequently we were unable to send out any of this variety.

The area under nursery this summer is made up as follows :—

	Acres.
One year maples	11
Two year ash	9
One year ash	11
Two year elm	½
One year elm	3½
Conifers	1½
Total	36½

It is still too early in the season to form any correct estimate of the number of seedlings which will be available for distribution next spring. The stock should, however, be exceptionally good as the season so far has been particularly favourable and the growth of the seedlings very strong.

Last year owing to the impossibility of collecting elm seed, several pounds were purchased in the eastern United States. This seed came up fairly well after sowing but the seedlings were completely killed out during the winter. This shows almost conclusively that seedlings of elm grown from seed matured in the east are not hardy enough for this country. About half an acre of seedlings from native seed came through without injury.

This spring the elms in the Qu'Appelle valley bore a good crop of seed, and we were able to collect sufficient to sow 3½ acres. As this is one of our best trees for prairie planting it is unfortunate that so much difficulty is experienced in collecting the seed in certain seasons.

CONIFERS.

On page 10 of last year's report is given a list of the conifers being raised from seed on the nursery.

With the exception of 1-year seedlings of *Pinus excelsa* (Himalayan pine), which were badly killed during last winter, all the varieties have come through very well. *Pinus ponderosa* did not stand the winter as well as the others but came through fairly well and may turn out better next spring.

Seedlings of Norway spruce, balsam and white spruce were not injured in the slightest.

Scotch pine, murrayana pine, cembra pine, and pinus flexilis, have all made exceptionally strong growth.

The following numbers (approximately) of two-year old seedlings were transplanted into beds and are doing well :

Scotch pine	20,000
Pinus murrayana	10,000
Pinus divaricata	1,000
Picea pungens	30,000
Picea alba	1,500
Total	62,500

Of all the trees growing on the nursery the native larch, or tamarac, gives the greatest promise as a hardy, rapid-growing variety for general prairie planting. Our experience would show that it is an exceptionally easy tree to transplant and appears to be suitable to a great variety of soils. The seedlings planted here were obtained from the swamp in the Spruce Woods reserve. They were planted in nursery rows for two years and then set out on backsetting, absolutely without protection or shelter of any kind. The growth the first summer was about a foot. The second summer the average growth was 18 inches, many of the trees making as much as 3 feet. Of the number set out in 1904 and 1905 (approximately 6,000), we have not lost a single one from winter killing, and not 1 per cent died after transplanting. This is a much better percentage than we find in any of the native broad leaf trees. We have not yet been able to obtain seed of the native larch but hope to be able to make arrangements for the collection of some during the coming summer.

The European larch grows readily from seed. We have growing here several four-year old plants, raised on the nursery which appear perfectly hardy. They, however, are considerably damaged by rabbits each winter, which causes a deformed misshapen growth.

PERMANENT PLANTATIONS.

The plantations made in 1904 and 1905 have made most satisfactory growth. The belt on the east and part of north side, consisting of five rows—two rows maple, two rows cottonwood and one row willow—already forms a good protection to the plots

which it borders. By the fall this belt should be 10 to 12 feet high. The trees now cover the ground so thoroughly that further cultivation will not be necessary.

A three-quarter acre plantation of tamarac and spruce set out in 1904 has made exceptionally good growth. An acre of tamarac, spruce and Scotch pine set out 1905 has also done very well. The Scotch pine, which were three-year old plants imported from France, suffered a little from the strong dry winds in the spring. Several that had died were taken out and replaced by others this spring.

It would seem that when first planted, a certain amount of shelter is necessary for the Scotch pine, that is, sufficient to collect snow and keep the young plants well covered. Apparently they are not injured in the winter, but as soon as the snow goes, leaving them exposed to the winds and the effects of thawing and freezing in the spring, the needles become browned and sunburned. In some cases the plants may appear absolutely dead and most of the needles drop off; but a very large number recover and send out fresh shoots as soon as growth starts. In the plantation mentioned above, when filling the blanks this spring, some rows were not disturbed at all. If a plant appeared to be dead another was set immediately beside it. We find that a great majority of those then supposed to be dead are now growing vigorously.

This year several thousand four-year transplanted spruce and Scotch pine raised from seed in our own nurseries were available for planting. An acre of permanent belt set 3 feet apart each way, was put out on the north belt. Three acres of Scotch pine planted alone, with trees 3 feet by 3 feet apart, was set out on east belt, and another acre with two rows of pine and one of spruce, to the northeast of the house. Altogether five acres of permanent evergreen plantation, or a total of about 25,000 young plants, were put in. The trees at present appear to be in splendid condition, nearly all having sent out vigorous shoots.

The plants were set in land which last year had grown a crop of seedlings. The ground was ploughed and worked up in the fall. In the spring the rows for the trees were marked out by making shallow lines with a hoe drill, some of the teeth having been removed to make the rows the necessary distance apart. The trees were set in holes dug with spades. In this manner it took five men eight hours to set out an acre. Allowing a foreman's wage of 20 cents per hour and men's wage at 16 cents per hour, marking rows 20 cents, we find the actual cost of planting to be $6.95 per acre.

This spring plantations of the following varieties and mixtures were set out :—

No. 1. Cottonwood, 3 feet apart each way, size, 1 acre.

No. 2. Cottonwood and maple, alternate rows, 3 x 3 feet, 1 acre.

No. 3. Maple and birch, alternate rows, 3 x 4 feet, 1 acre.

No. 4. Elm and ash, alternate rows, 3 x 3 feet, ½ acre.

No. 5. Russian poplar, 1 year rooted cuttings, 4 x 4 feet, ¾ acre.

The preparation of the ground was well worked backsetting, ploughed again as deeply as possible late in the fall. The cottonwoods were set in holes made with a planting iron, the other varieties being planted in deep furrows made by the plough.

The cost of planting based on the actual time of men and team employed was as follows :—

Plantation No. 1....	$ 6 05
" 2....	8 70
" 3....	7 20
" 4....	3 60
" 5....	4 40

It will be noticed that plantation No. 2 cost considerably more than any of the others; the reason for this being that the maples used were very large, averaging over 4 feet high and some 6 feet. These were picked out from two-year seedlings as they were too large for shipping. It shows the extra expense entailed in handling large trees as compared with small ones of, say 18 inches to 2 feet in height. We find too that a greater proportion die after transplanting as, owing to the larger root system, they are apt to be put too shallow.

To keep these plantations cultivated will entail an additional outlay of about $2 per acre this summer, making the original cost of planting about $9 per acre. About $2 per annum for the next two seasons will also be required, bringing the total cost of establishing plantation up to about $13 per acre.

It is intended to treat these plantations as a growing crop. As soon as the wood becomes large enough for use it will be cut. Careful records will be kept of all expenditures in connection with each plot and also of the yields. In this way it can be determined what varieties and what mixtures are likely to prove the most profitable. Judging from the present rate of growth of cottonwood it is expected that thinnings will be made about six years from now, from which it is expected to obtain wood large enough for summer fuel. As the plantation grows older the wood will become larger and consequently more valuable.

It is hoped to set out several more plantations of this character in the future if a sufficient area of land on the nursery can be spared for this purpose.

The whole of the quarter section at present at our disposal has now been brought under cultivation, excepting fifteen acres which is used as a pasture.

This summer about thirty acres have been broken and will be backset later in the season. Fourteen acres have been summer-fallowed and will be divided into plots and sown with tree seeds in the fall. Twenty-five acres are under oat crop, three under barley, and nine and a half under rye grass for hay.

Owing to the very favourable weather during this and the past two seasons everything planted on the nursery has made most satisfactory growth. The shrubs planted along the drives and bordering the lawns have done well, though a few of the more tender varieties, owing to the lack of protection during the winter and the absence of snow, have been considerably killed back. Those suffering no injury, although absolutely unprotected are: the lilacs, Tartarian honeysuckle, Siberian dogwood, Spirea billardii, Spirea Van Houtei, Spirea arguta, Caragana and Cinnalian maple. As the trees put out for shelter afford more protection it is hoped that some of the more tender kinds will prove more successful.

The lawns have greatly improved this summer and the drives, which have all been gravelled, are now in good condition, adding greatly to the general appearance of the nursery.

As you are aware, the small portion of land (17 acres), which was kindly put at the disposal of this branch, to be used for nursery purposes, by the experimental farm, will no longer be required after this season, as we are now in a position to grow all the stock required on our own nursery. In this connection I would like to point out the difficulty we are likely to experience in regard to the accommodation of the labourers. When working on the experimental farm it was possible to obtain men who could board in town as the farm is only distant from it a few minutes' walk. The nursery station is about two miles from the centre of town and at certain seasons the roads are extremely bad. Consequently it would not be possible, unless very high wages were paid, to get men living in town to work so far from their homes. In the spring and in the fall we find it necessary to employ as many as twenty or more hands. At present we have only accommodation on the nursery for boarding six or seven. In order to carry on the work at all satisfactorily it is absolutely necessary that additional accommodation be provided, and I would therefore recommend that a suitable house be erected on the grounds as soon as arrangements can be made to do so.

In other matters the nursery is now well equipped and in a position to raise from two and a half to three and a half million seedlings annually.

Owing to the fact that the report this year has been called for so early in the season it is not possible to furnish information as to the exact numbers of seedlings available for distribution next year, and as to the growth of seedlings and plantations, which are matters of considerable interest.

Your obedient servant,

NORMAN M. ROSS,

Assistant Superintendent.

APPENDIX No. 2.

REPORT OF R. D. CRAIG, F.E., INSPECTOR OF FOREST RESERVES.

OTTAWA, August 1, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour to submit herewith the third annual report of my work carried on under your direction.

Owing to the transfer of the administration of the forest and game reserves from the Timber and Mines Branch to this branch and the extension of the forest investigation work it was necessary for me to be relieved of all duties in connection with tree planting on farms and devote my entire attention to the forest reserves.

At the time of writing my last report I had just completed a forest survey in the Turtle Mountain Forest and Game reserve and was starting a similar one in the Moose mountain reserve. This season I have placed a party under Mr. Wallin to study the forestry conditions in the Riding Mountain Forest and Game reserve which is perhaps the most important Dominion reserve at present.

I may say that the method which I have followed in conducting the forestry survey is somewhat similar to that followed by the United States forestry service, which consists in measuring with calipers at 4½ feet from the ground, all the trees in strips 2 rods wide. The distance between the strips varies with the nature of the stand ; where dense, or variable a one-eighth mile or a one-quarter mile, but where burned over or very homogeneous, one-half or one mile is sufficiently close. At the end of each one-quarter mile (or 1 acre) a description of the topography, soil, undergrowth, and general sylvicultural conditions is written on the back of the tally sheet and a new one started. Tally sheets are also changed with each change of type. From these notes and a rough sketch map we are enabled to make a map sufficiently accurate for forestry purposes. The party usually consists of four men, one who goes ahead with a hand compass and drags the chain, one caliper man on each side of the chain who measures all the trees over 3 inches diameter breast-high within 1 rod of the chain; the fourth acts as rear chainman and tallyman. The caliper men call out the number of 12-foot logs which they estimate can be cut from each tree as they give in the diameter.

In addition to the valuation survey a certain percentage of trees which appear to be average trees of each diameter class are cut down and sawn into 10-foot sections, and at each cut the rate of growth for each decade taken. In this way it is possible to determine when the tree ceased to grow at a profitable rate. We are also enabled by this means to tell how much may be harvested annually without reducing the capital stock.

Sample plots of reproduction usually 1/40 acre are taken here and there to determine how many young trees of each species are on the plot. The age and rate of growth of these are also taken.

The forester endeavours also to become familiar with the local economic conditions of the reserve in order that he may be able to cope with all administrative difficulties.

I spent six weeks in the Riding Mountain reserve this summer and one week in the Cooking Lake reserve, near Edmonton, and I hope before winter to be able to inspect the other reserves.

I beg to report on the condition of the reserves which I have inspected.

TURTLE MOUNTAIN FOREST AND GAME RESERVE.

The Turtle Mountain reserve covers only 69,920 acres, but being situated as it is in the midst of a treeless prairie country now thickly populated it is of considerable importance.

The hills rise above the surrounding prairie from 300 to 500 feet, and being full of lakes and sloughs act as an immense reservoir for water which supplies natural irrigation to the prairie below. Numerous streams flow down from the hills in all directions; some of them go to form the Pembina and the Whitemud rivers, but many of them sink into the soil after leaving the forests. Approximately 15,000 acres of the reserve is under water, leaving only 55,000 acres of timber producing land.

The soil in the reserve is mostly a clay loam with a few boulders, but the configuration is so rough and so much of the area is in muskeg and sloughs that it is unsuitable for agriculture. Attempts which I saw to produce grain were failures. There is excellent pasturage, however, especially in the brûlés where the pea-vine and vetches grow in a dense mass 4 to 5 feet deep. The grass around the edges of the sloughs is very luxuriant and makes excellent hay. Small deposits of coal have been discovered in the Turtle mountains but not in large enough quantities for commercial exploitation.

No traces of conifers were found, and if they ever did grow in these hills fires have destroyed them, leaving only those species which are able to reproduce by suckers or coppice. The mature stand is now composed of Aspen (*Populus tremuloides*), 43 per cent; Balm of Gilead (*Populus balsamifera*), 14 per cent; paper birch (*Betula papyrifera*), 21 per cent; bur oak (*Quercus macrocarpa*), 9 per cent; green ash (*Fraxinus viridis*), 8 per cent; elm (*Ulmus americana*), 5 per cent, and a few scattered Manitoba maples (*Acer negundo*). There was originally a much larger proportion of oak but the demand for oak logs and posts has been so great that very little now remains.

There is an extremely dense growth of underbrush, even in fairly dense stands of timber, and this makes seedling reproduction difficult and also increases the fire danger.

The underbrush is composed chiefly of the following species, named in the order of their abundance: hazel, high-bush cranberry, various species of willows, raspberry, Saskatoon berry, rose, cherry and dogwood.

Since the advent of the settler about twenty-five years ago forest fires have been so frequent and so destructive that only 1,600 acres of timber has escaped; on 6,400 acres the timber has been partially destroyed, and the remainder is entirely devoid of large timber. There is, however, an excellent reproduction on the burned over area which, if protected, will soon form as good or better stand than the original.

Owing to the greater power of reproducing by suckers the aspen forms 69 per cent of the new growth, while the balm forms 12 per cent, birch 7 per cent, ash 6 per cent, oak 4 per cent, elm 1 per cent, maple 1 per cent.

The following table shows approximately the quantity of timber at present on the reserve:—

TIMBER on the Turtle Mountain Forest and Game Reserve.

UNBURNED AREA, 1,611 ACRES.

Species.	Trees per Acre.	Cu. ft. per Acre.	Total cords.	Saw material Ft. B. M. per acre.	Total.
Aspen	94	1,103	19,825	134	215,000
Balm	31	390	7,007	209	337,000
Birch	46	428	7,695	74	20,000
Ash	19	59	1,068	15	4,000
Oak	17	77	1,379	4	7,000
Elm	12	33	593	17	28,000
Total	219	2,090	37,567	453	731,000

Partially Destroyed Area, 6,371 Acres.

Living Trees.

Species.	Trees per Acre.	Cu. ft. per Acre.	Total cords.	Saw material Ft. B. M. per acre.	Total.
Aspen	26	377	26,778	69	442,000
Balm	8	90	6,414	20	125,000
Birch	5	44	3,093	31	20,000
Ash	3	7	512	....	....
Oak	4	32	2,290	2	13,000
Elm	2	6	434	·4	2,000
Total	48	556	39,520	122·4	602,000

Standing Dead Trees.

Species.	Trees per Acre.	Cu. ft. per Acre.	Total cords.	Saw material Ft. B. M. per acre.	Total.
Aspen	19	211	15,010	....	....
Balm	9	85	6,044	....	....
Birch	8	68	4,828	....	....
Ash	10	15	1,088	....	....
Oak	5	15	1,074	....	....
Elm	1	3	206	....	....
Total	52	397	28,250	....	....

About 10 cords per acre dead and down timber sound enough for fuel—63,710 cords.

Total stock : 77,087 cords green fuel, 91,960 cords dry fuel. Saw material: 1,333,-000 feet B.M.

Several small saw-mills have operated in these forests, but at present only one is left and it takes only a small number of logs for a limited local trade.

The day of log buildings is past in that district so that now the main uses of the reserve are to supply fuel and fence material, to protect the watershed, to harbour game, to serve as a pleasure and health resort, and to ameliorate the climate.

Farmers living within a radius of fifty miles come to the reserve every year for their supplies of wood, and the following table shows the output in the last three years:

Timber taken out of Turtle Mountain Reserve under Settlers' Permits.

Year.	No. Permits.	Dry Woods.	Greenwood or for sale.	Logs.	Posts.	Roof Poles.	Rails.	Revenue.
	-		Cords.	Ft. B. M.				$ cts.
1903	198	1939	219	35,034	2400	200	75	302 42
1904	638	6691	683	14,768	4300	....	....	542 04
1905	444	4549	560	25,200	3350	1950	500	353 75
Average..	427	4393	487	25,001	3350	717	192	401 07

From our measurements of the rate of growth the following table gives a conservative estimate of what may be expected from the dense stands of reproduction now one to twenty years old :—

Age.	No. Trees Per Acre.	Average Diameter Breast High.	Average Height.	Average Vol.	Yield Per Acre.
		Ins.	Ft.	Cu. Ft.	Cords.
10	4000	1·5	13·5	·1	4
20	2500	3·2	28·0	·8	22
30	1200	4·7	38·0	2·4	32
40	850	6·0	46·5	4·3	41
50	625	7·2	51·0	6·8	47
60	425	8·7	54·0	11·1	52
70	335	10·1	56·5	14·0	55
80	300	11·1	58·0	17·4	58

It will be seen that by cutting every forty years, which is a long enough rotation for fuel production, an annual cut of one cord per acre, or 55,000 cords, may be made without reducing the capital stock. This amount will supply a farming area of between two thousand and three thousand square miles with fuel and fence material, and at the low price of $1 per cord would bring an annual revenue of $55,000.

This supply of wood in the midst of a bare prairie country is of great value to the settlers and there is no reason why, if protected from fire and illegitimate cutting, there should not be sufficient timber produced on the area now reserved to supply the local demand for all time.

Cutting.—There has been a great deal of wasteful cutting in the Turtle mountains, and it is the common practice still to cut down a large tree and take only 8 to 12 feet of the butt and leave the rest to rot or burn. The stumps are, as a rule, inexcusably high ; there is no reason for having more than a 1-foot stump for poplar. Heretofore cuttings have been made wherever convenience suggested, but if the forest is to be made productive the exploitation of the timber must be done systematically and thoroughly. Three or four cutting areas in different parts of the reserve should be laid out annually and operations restricted to these. The aspen will reproduce naturally, but it is advisable that some more valuable species be planted, and this spring an experiment with Scotch pine was started which promises to be successful.

Fire.—Fire has certainly been the greatest agent of destruction in this reserve and hardly a year pases but some part of the reserve suffers from its ravages. The fires of largest proportions occurred in 1879, 1881, 1885, 1897, 1903, 1905, and again this spring fire burned over a considerable area.

The fires of 1879, 1881 and 1885 seemed not to have done much damage but left fire scars on the trees along the south side of township 1, range 19.

The first serious fire seems to have been that of 1897, which came from the Dakota side into township 1, range 21, near Boundary lake. Some say that it was caused by the Indians who, under the Dead and Down timber law, were given the dead timber and that they set fire to the forest in order to increase the supply of this dead timber. Others say that the American farmers set it in order to clear their farms. Whatever the origin, it destroyed nearly everything in townshin 1, ranges 20 and 21, as is shown in the accompanying map.

The fire of 1903 burned over almost the same territory as that of 1897 and killed thousands of acres of splendid reproduction, besides much timber that had escaped previously. The first start of the fire seems to be at or across the American boundary, but it is evident that it was started in several other places later with the intention of making a clean job of removing the forest so that the land would be thrown open for settlement. This fire burned all summer and any attempts that were made to put it out seem to have been futile.

In 1904 there were a couple of small fires in township 1, ranges 20 and 21, but these were prevented from spreading far.

In 1905, another burned about 6 townships in 1-21. The origin of this fire is not known, but it is thought that it was started by settlers burning the hay meadows which they lease within the reserve. The burning of hay meadows can be done before the snow is out of the woods and no damage will result, but later burning should be severely penalized. At present the greatest carelessness is shown by those holding hay leases and it may be necessary to cancel all leases in future unless they can be more strictly regulated.

This year, also, fires have been started by both Americans and Canadians, and the ranger had the utmost difficulty in preventing the burning of the entire reserve.

It is without question that the recurrence of these fires must be stopped if the forest reserve is to be maintained, and in order to accomplish this it is necessary to impress the public with the fact that the government is not going to throw the land open for settlement and that it is prepared to protect its property against wilful or negligent destruction.

The first step in this direction is the eviction of the squatters who in c of the government orders have settled within the reserve and are doing all in their power to rid the land of trees and to encourage other squatters. They have been immune from prosecution so long that they have grown bold in their trespass. Now that the reserves have been set aside by Act of parliament the administration will be able to act with a stronger hand.

Forest Ranger Walkinshaw is constantly employed in guarding the reserve and during the dry seasons in spring and fall is given assistance in patrolling, but owing to the lack of trails throughout a large part of the reserve and the impassability of those that have been cut it is impossible to patrol the district as it should be done, and a fire might burn for a day or more before a ranger could get at it through the fallen timber and dense undergrowth. On the accompanying map a system of trails has been laid out, the construction of which I hope will shorty be completed. This year the ranger, with the assistance of one man, is improving the main trail through range 20, and later the others will be fixed up. It is not expensive work making trails through this country and the outlay will be quickly repaid by the facility it will give the rangers in putting out incipient fires.

The ranger has a shack on section 9, 1, 20, which is well situated in order to watch the southern side of the reserve, but there should be two or three stations along the north side, and I would advise the appointment of three fire guardians whose houses are near the northern boundary and who would in event of a fire report it to the ranger and take what immediate steps are necessary to extinguish it. These stations should be supplied with telephone communication with the ranger's shack and with Boissevain. A local telephone system is about to be established in the neighbourhood, I believe, and this service can then be easily provided.

Fire fighting tools, such as shovels, axes, hoes and pails, should be kept at each of the stations ready for use.

Fungi.—A very large percentage of the old timber and much of the younger are being destroyed by fungi, chiefly polyporus ignarious. Fire scars enable the fungus to gain access to the wood of the tree and it soon permeates the whole trunk destroying the wood. Finally it fruits by means of the dark hoof-shaped brackets so often seen on trees, and the spores attack other trees. There is no practicable method of combatting this disease except by removing diseased trees and this will be done as soon as possible by directing the settlers' cutting to affected stands.

Before the fires the Turtle mountains were very much more attractive from an aesthetic standpoint, and even yet there are many picturesque little lakes whose banks are wooded. Of these, Lake Max is becoming quite a favourite summer resort, and many people take the opportunity of a change in scenery from the bare level prairie or the dusty town for the cool and refreshing woodland scene.

There are some pickerel in the lakes but the introduction of black bass would make the resort still more popular.

The reserve has the support of the best public opinion, and if a firmer hand were used in the administration the favour of even those who now would like to see it thrown open would be won.

MOOSE MOUNTAIN FOREST AND GAME RESERVE.

Owing to the lateness of the season before we were able to start work in the Moose mountains a reconnaissance survey was all that was possible, but as the conditions were very similar to those in the Turtle mountains, and the reserve mostly covered by reproduction which had not reached a merchantable size, it was considered that it would be all that was necessary in this reserve. Where there was large timber we ran survey lines, but for the most part cruised in parties of two and measured sample areas and made occasional stem analyses.

The Moose Mountain forest and game reserve is situated in townships 9, 10, 11, ranges 2, 3, 4, 5, west of the 2nd principal meridian, in Saskatchewan, and contains 163 square miles of rough, hilly and forested land. One peculiar feature of the Moose mountain topography is that though the lakes and sloughs cover nearly one-fifth of the area there are hardly any streams flowing out of the district. There is subterranean drainage, however, which supplies the surrounding prairie with excellent water. It is said that when the wind blows from the direction of the hills the water in the wells rises quite perceptibly.

The soil is mostly a clay loam with considerable gravel. The lake shores are nearly all of clean gravel.

Where not too rough agriculture would be possible, but attempts at wheat-growing do not seem to have been very encouraging. There is splendid grazing in the reserve and many cattle range there winter and summer. The grass around the sloughs makes excellent hay and during the summer the pea-vine provides abundance of feed. In the more open places, especially along the west side, the upland grass or 'prairie wool' is cut and makes the best of hay. The cattle which are allowed to pasture in the reserve are doing considerable damage to the reproduction and one can easily tell by the appearance of the stand whether cattle are running in it or not. The trees are more scattered, many are scarred, the growth is retarded and shrubby trees like the willows predominate where grazed. It will be necessary to restrict the grazing to within harmless limits in future.

The maple, oak and elm found in the Turtle mountains are absent here, and the mature forest is composed approximately of aspen 82 per cent, balm 8 per cent, birch 9 per cent, ash 1 per cent.

Most excellent reproduction, chiefly aspen and balm, has followed the fires of 1885 and 1897, and, if protected as it has been of late, will soon reach a merchantable size. The nine-year old trees are now eight to twelve feet high, and the 19-year old twenty-five to thirty feet, and growing densely. The trees are tall, straight and clean and will make good wood.

The area covered with merchantable timber may be roughly estimated at 4,000 acres, about 80,000 covered with reproduction and the remaining 20,320 in water or prairie.

The average yield per acre is about 23·4 cords. There is therefore about 93,600 cords of green wood, and there is at least 100,000 cords of dry wood available for fuel. Of saw material there is about 4,520,000 feet, B.M., aspen; 760,000 feet, B.M., balm; 368,000 feet, B.M., birch, but this is so scattered that it is hardly available for milling.

Very little damage is being done by the cutting, and as Forest Ranger Rutherford is directing the removal of dead wood systematically the forest is being put in much better condition thereby.

The following table shows the amount of wood which the reserve supplies to the settlers, and I may say that nearly all of this wood was taken out under the free permits granted to homesteaders :—

Year.	No. Permits.	Building Logs.	Roof Poles.	Fence Rails.	Fence Posts.	Cords Fuel.
1903	1,402	74,528	7,750	27,735	7,488	5,308
1904	1,286	230,117	27,597	26,850	50,068	5,211
1905	813	128,230	20,901	15,264	22,865	3,909
Average	1,167	144,292	18,749	23,283	26,807	4,809

The surrounding country has been settled within the last few years and therefore the demand for building and fencing material has been larger than it will be after this.

Fires.—In 1885 a very serious fire, supposed to have originated from one of the numerous prairie fires, swept over almost the whole reserve and left the timber standing on only a few sections around Fish lake and some towards the northwest corner of the reserve. Even these were considerably injured by a lighter ground fire. Owing to the small number of settlers at that time, very little could be done to check the progress of the fire and it was allowed to burn itself out. Traces were found of some fire nearly every year, but no serious damage was done until 1897 when another fire ran over a large area of the same country and destroyed the reproduction which was then eleven years old.

This fire is supposed to have been set in two places in the reserve by ranchers, and the efforts to back fire, no doubt, spread the fire still more widely. The settlers fought this fire well and managed to save most of the old standing timber and also considerable of the reproduction, as is shown in the accompanying map.

In 1900 another fire destroyed a strip of reproduction about one-half mile wide, adjoining the prairie on the west side. One of the chief sources of danger to this reserve is the Canadian Pacific Railway engines which every year set numerous prairie fires along the line, and it takes the utmost vigilance of the ranger to keep them from running into the timber. Now that the land is being put under cultivation this danger will be lessened.

The devolution from forest to prairie through fire can be seen in all the stages along the edge of these mountains and the Indians tell us that the forest once extended over a large area which now through fire and grazing is a rolling prairie.

Trails.—As shown on the map a trail was built by the government almost through the mountains, in range 3, in 1900. It has been cleared of all trees for a chain wide, and if completed to the northern edge of the mountains, and one or two small bridges put in where necessary there would be sufficient travel to make the trail useful as a fire-guard and a means of patrolling the reserve. As it is now, it is growing up with dense reproduction of trees and underbrush and should be cleaned out again. One trail into the eastern end of Fish lake, one north from there to the prairie, and one from Arcola to Bennet's lake, are all the trails that are at all passable in the summer and these are very poor. It is therefore impossible for the ranger to patrol the reserve as he should.

This year we are having the road into Fish lake widened and the wet places corduroyed, and I would urge that the government road be completed, a trail made along the north side of Fish lake and west to the old Indian reserves through the centre of the Forest reserve. There are old trails running north from Bennet's lake which were passable when the water was lower and could now be altered with very little expense so as to be of service.

For the last four or five years the water has been rising in the lakes in the Moose mountains and this can, I think, be attributed largely to the growth of the trees and

the protection afforded the water by the dense young stand. Fish lake is now about 4 feet higher than formerly, and where they used to drive along the shore is now deep water the year around. The Northwest Mounted Police have rendered valuable assistance in protecting this reserve from fire and timber stealing.

There are several squatters in this reserve also, who should be removed as soon as possible. I found public opinion generally very much in favour of the forest reserve policy, and the settlers and townspeople are all anxious to have the forests protected. As a summer resort it is even more popular than the Turtle mountains, and in August there are between three and four hundred campers on Fish lake which is the largest sheet of water in the mountains. This is a beautiful lake and provides excellent fishing as well as boating and sailing facilities.

There are elk and jumping deer in the woods, and in the fall the wild duck cover the sloughs and lakes in thousands. Partridges and prairie chickens are also plentiful. The muskrats are taken out in large numbers every winter, and there is one colony of beaver near Fish lake which is being carefully protected.

These mountains are situated in the midst of one of the best wheat-growing sections of the west, and the productiveness of the surrounding prairie may be largely attributed to the shelter afforded from the wind, and the fact that the water supply is conserved by the forests in winter and supplied to the fields during the summer through underground channels.

The forests are in a most hopeful condition and with continued protection against fire, over cutting and grazing, will soon become very productive.

RIDING MOUNTAIN FOREST AND GAME RESERVE.

The Riding mountain, Duck mountain and Porcupine mountain reserves differ from the other reserves in the middle west in that they have in them considerable saw material of the more valuable species, such as spruce, larch, balsam and jack pine, which grow in stands yielding as much as 4,000,000 feet, B.M., per square mile. The deciduous trees are represented by the aspen, balm, birch, oak, ash, elm and maple. In the Riding mountains the coniferous species are found chiefly at the higher altitudes; the aspen, balm and birch grow everywhere, but the oak, ash, elm and maple are confined to the lower and chiefly north and east slopes. The spruce reaches a large size, frequently over 36 inches diameter, breast-high, and 90 feet in height. There is a large amount of water in the Riding mountains, but the drainage is much better than in the Moose and Turtle mountains and deep ravines with swift streams are more characteristic of the topography than sloughs. There are numerous lakes and most of them are quite large. A considerable area, especially near the height of land, is covered with spruce and larch muskeg, which makes travelling through the reserve almost impossible in summer.

As in the other reserves fire has done great damage to the forests and in some places, especially along the Strathclair trail, almost prairie conditions have been produced. Along the southern part of the reserve the fires have produced a park-like country where grassy glades run in betwen the bluffs of trees which have escaped the fire.

The soil is chiefly a clay loam with some boulders and shale. The shores of the lakes are usually quite gravelly and the beds of the streams filled with boulders.

Cutting.—There are at present nine timber berths, covering in all about 114 square miles in this reserve, but most of them have now been cut over and have ceased operations. The Shaw Bros., of Dauphin, are perhaps the largest operators in the reserve at present, and they are lumbering in a very careful and conservative manner. They have exercised the utmost care with fire and utilize as much of the merchantable timber as could be expected. This firm contemplates starting experiments in replanting cut-over areas next spring which is a good indication of their interest in forest conservation.

A great deal of the cutting is now being done by portable saw-mills which locate along the edge of the reserve and saw wood taken out under the settlers' permits. The settlers may cut their own logs and haul them to the mill but the usual practice is for the millman to collect the permits and take out the wood himself. This system enables the farmer to obtain building material very cheaply, but it has been greatly abused and will have to be discontinued entirely unless it can be kept in better control, for annually large amounts of timber are cut illegally and since these millmen have no interest in the forest and are entirely irresponsible the most wasteful cutting is followed. On account of the growing scarcity of the coniferous species it will be necessary to discriminate against their exploitation and favour the use of poplar which grows in abundance and reproduces readily. The cutting of green coniferous species for fuel should be prohibited entirely, but the removal of dead timber and diseased timber be encouraged. There is no reason why the reserve should not produce a good revenue without causing any hardship to the settlers who are benefited by its existence.

Since the Forestry Branch has taken charge of the reserves new regulations have been made which aim at the protection of the conifers, the removal of dead and diseased timber and the restriction of cutting areas. The portable saw-mills will also be under closer supervision.

Squatters.—Perhaps the most serious administrative difficulty in the Riding mountains is the handling of squatters, of whom there are fifty, chiefly Galicians and half-breeds. These people, though warned that they could not secure their patents, have gone into the woods and cleared little patches for their homes and in doing so have systematically set fire to the surrounding forests. Under the unstable conditions of the reserve boundaries before the passing of the Forest Reserves Bill some of the squatters did receive their patents and the success of these has encouraged the rest to persist in their trespass. The class of people who are squatting are not particular what kind of land they settle on and will never farm well or extensively. As citizens they are undesirable and have very little claim to consideration. The influx, especially of Galicians, is steady and unless severe measures are taken to rid the reserves of those at present there, and to prevent further encroachments, it is useless to attempt to protect the timber.

Game.—Moose, elk and jumping deer are very plentiful in the north and eastern part of the reserve, but towards the south where the Indians and half-breeds live there are few left since these people kill them without respect to season or sex and have practically exterminated them. There is good fishing in some of the lakes, and ducks and partridges are quite plentiful.

From a Hydrographic Standpoint this reserve is probably the most useful of the Dominion forest reserves since it is situated at the headwaters of nearly half of the tributaries of the Assiniboine river and of all the streams which water the famous Dauphin plains. The value to the surrounding agricultural districts of the wood produced on this reserve can hardly be estimated, and it is satisfactory to find that locally (except for the squatters) the maintenance of the reserve is strongly upheld, and any action to futher the protection and improvement of the forest in accordance with the object of the reserve will receive the support of the communities affected.

COOKING LAKE FOREST AND GAME RESERVE.

The Cooking Lake reserve is situated in the Beaver hills, near Edmonton. This reserve has probably suffered more from fire than any of the other reserves, and there is at present hardly a square mile of virgin timber left. The original stand was spruce, larch, aspen, balm, birch, with some jack pine and balsam. Now the conifers have almost all disappeared and only an odd old spruce or larch which has been protected by a muskeg or a hill remains to show that there was once a coniferous forest on

these hills. Reproduction of aspen and balm is coming up thickly over almost all of the reserve, but some of it has been burned over three or four times and is now beginning to lose its vigour. In these places it will be necessary to replant if the forest is to be maintained.

The country about this reserve is new and there is a great inflow of settlers, many of whom do not know good land from bad ; consequently they drop down like locusts on every bit of government land and proceed to rob it of the only asset is possesses—the timber.

The soil in the hills is almost all of a light coloured clay or gravelly, and is not fertile enough for agricultural crops even where level and free enough of muskegs and sloughs to permit cultivation. One man who was unfortunate enough to locate in these hills told me that after five years' hard work (and I could see that he had been industrious) he had not succeeded in raising enough to feed his horses. It would seem that the government would make a serious mistake to settle this poor land when there is so much excellent land available. Disappointed settlers are poor advertisements, aside from the fact that they destroy the timber which, in a very few years, when the adjacent country becomes all cleared, will be of great value to the same settlers who are now intent upon destroying it.

The boundaries might be extended to the south to include the north $\frac{1}{2}$ of township 51, range 20, and the northwest $\frac{1}{4}$ of township 50, range 19.

To cope with the fire danger at all efficiently the department should appoint a special ranger to guard the reserve, as the present forest ranger has much too large an area of timber land to look after to enable him to give the attention he should to the reserve.

In view of the rapid influx of settlers to the Northwest, many of whom settle in advance of the surveys, I would strongly recommend that the forested country within reach of settlement be thoroughly explored and that all land which is not suitable for agriculture, but is capable of producing forests be set aside as permanent forest reserves, within which settlers will not be allowed to locate. It is very much easier to get rid of a squatter before he has made any improvements than after he has built a home for himself. These isolated settlers in a timbered district are the greatest menace to forest protection, as they are constantly setting fire, and it would pay the government to employ a much larger number of rangers to constantly guard the forests of the Northwest from fire and prevent settlement within them.

Adequate forest protection is possible only under the reserve system, since forestry and settlement are two irreconcilable factors in a new country.

With this object in view I would suggest that as early as possible examinations be made by this branch of the following districts ; the foothills of the Rocky mountains in Alberta, McLeod river, Lac la Biche, the sandhills north of Prince Albert, and the country around the west, north and east of Lake Winnipegosis.

Your obedient servant,

ROLAND D. CRAIG.

APPENDIX No. 3.

REPORT OF HUGO CLAUGHTON-WALLIN, F.M., ASSISTANT IN FORESTRY.

DAUPHIN, MAN., July 28, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour to submit to you my report for the year ending June 30, 1906.

After July 1, 1905, I continued the inspection of tree plantations set out by the Forestry Branch, which I had started in the beginning of June the same year. The parts I visited were Western Manitoba and Eastern Saskatchewan. It was for me a very pleasant sight to see so many fine groves of trees scattered over the prairie forming excellent wind breaks and lending beauty to the otherwise rather dreary and monotonous landscape.

The plantations consisting generally of Manitoba maple, green ash, cottonwood, elm and willow, were mostly all in good shape, the percentage of dead trees being very small; I should estimate it at 10 per cent to 15 per cent. The farmers seemed well satisfied with the work of the department. Quite a number of them expressed a desire to receive some spruce or pine seedlings, and I would respectfully suggest that a few of these species should if possible be distributed to farmers who, by previous successful planting, had proven themselves well capable of giving the young trees the necessary attention.

At the end of October I finished the inspection and went to Indian Head, where, for two weeks, I assisted Mr. Ross, in the taking up and the heeling in of the seedlings for this spring's distribution. Altogether, two millions of trees were in this way prepared for the winter. They were all in excellent condition, being thoroughly ripened in spite of the fact that they had attained a very good growth.

After my two weeks' stay at Indian Head I returned to Ottawa, where I remained in the office until spring.

On April 5 I received notice to leave for Indian Head where the shipment of trees to the applicants was to begin. The heeled-in seedlings had survived the winter splendidly and ought to prove excellent plant material.

When through with the packing I went down to Sewell, Manitoba, to superintend the planting of Scotch pine seedlings on the Spruce Woods Forest and Game reserve. This plantation was begun two years ago and promises to be very successful. Strong, healthy-looking pines to the number of 17,000, were set out this spring in furrows ploughed 4 feet apart and the sod always thrown so that the perpendicular side of the furrow would come on the south side to shelter the young plants from the hot noon sun. The seedlings were put close to this side and about 3:5 feet apart in the row. The cost of planting these Scotch pine was about $15 per acre. I found the plantation of last year doing well, about 85 per cent living, which must be considered a very good result.

At present I am engaged in conducting a forest valuation survey of the Riding Mountain Forest and Game reserve in Manitoba.

The reserve as far as I have seen it has been well forested and is capable of supplying fuel and building material to a large number of settlers.

The chief species numerically is the aspen, and this makes excellent fuel and if sound, fairly good lumber. It is, however, being greatly damaged by a fungus disease (*Polyporus ignarious*) which threatens to spread throughout the reserve. It would be advisable to cut this diseased timber as soon as possible. The spruce is the most valuable species found on the reserve and is quite prevalent in some parts and reaches a large size, trees over 36 inches diameter, breast high, are frequently found. The other species of trees found on the reserve are larch, balsam, jack pine, balm of Gilead, white birch, elm, green ash, Manitoba maple, mountain ash, scrub oak, and several species of willow. Some large areas have been burned over, but in most places there is sufficient reproduction on the brules.

The chief source of danger to the reserve is the squatters who are encroaching on the reserve in many places, and who set fires every year in order to open up the country for settlement. The squatters are chiefly Galicians or half-breeds. If the timber on the reserve is to be protected these encroachments must be stopped.

I have at present seven foresters assisting me in the work of determining the quantity of timber on the reserve, the rate of growth of the various species and sylvicultural conditions generally.

In spite of very unfavourable weather we are making good progress and expect to complete the work by the end of September.

I have the honour to be, sir, your obedient servant,

H. CLAUGHTON-WALLIN.

APPENDIX No. 4.

REPORT OF A. P. STEVENSON, TREE PLANTING INSPECTOR.

NELSON, MAN., July 1, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour to submit the following brief report on the work done by me under your instructions as tree planting inspector in connection with the work carried on in this province by the Forestry Branch of the Department of the Interior.

On June 13 I commenced inspection work, but up to the present have not covered very much ground. On June 15 I went to Winnipeg to meet Norman M. Ross, assistant superintendent of forestry, and arrange with him about inspection work for the season. Messrs. Craig and Wallin who, during the past two seasons, have been engaged on this work in Manitoba, not being available this year, two new men, Messrs. Ross and Jacombe of the Yale Forest School, New Haven, Conn., who had joined the Forestry Branch, arrived in Winnipeg to take up inspection work. These men accompanied me for a short time, then left to take up the work of inspection alone in various parts of the province ; Mr. A. H. D. Ross taking the main line of the Canadian Pacific Railway from Rosser west to Kirkella; also the Miniota, Lenore and Yorkton branches. Mr. Jacombe commenced work at St. Claude on the Glenboro' branch, west to Souris, the Pipestone branch, Souris to Sinclair, Deloraine to Lyleton, Souris to Estevan, Sask. My own district will be principally in the Red River valley and on the Canadian Pacific Railway, southwestern, Winnipeg to Boissevain ; Canadian Northern Railway, Morris to Elgin; also the Emerson, Ridgeville, Stonewall and Gilbert Plains branches.

The spring was an extra early one, the warm weather in the month of April brought out the buds on the trees earlier than usual, the result being rather disastrous to some varieties of ornamental trees and more especially fruit trees.

The weather continued very dry for some time with cold, frosty nights and warm days, which was very trying on the young, newly planted forest trees. But owing to the trees being well packed and arriving at their destination in fine order, where planting was done well very little injury has resulted from the dry spell. And I might further add that to the wisdom of the Forestry Branch insisting on a thorough preparation of the soil before trees are given for planting belongs a good deal of the credit for this favourable showing in tiding over a dry period. Cottonwood appears to have suffered slightly from winter killing during the past winter in some parts of the Red River valley, notably in the Sperling district. The land there is a rich black loam ; on this soil the young trees make a rapid soft growth which failing to get fully ripened up by the closing in of winter the following spring will show more or less killing back of the previous year's growth. As the trees grow older and a hardier growth is made this trouble I have no doubt will disappear. With the majority of planters the green ash is very much in favour and giving increased satisfaction every year. When planted in alternate rows with Manitoba maple and set out 4 feet by 4 feet apart the growth is about equal to that of the maple.

During the whole of the month of June there has been abundance of rain; consequently the trees as a whole are looking well and making remarkable growth.

Of the trees sent out this spring, so far as inspected I would estimate that 95 per cent of the ash are living, 85 per cent of maple, and 75 per cent of cottonwood. The Russian willow is growing in favour and is frequently inquired after for the purpose of growing a snowbreak. A snowbreak is usually planted at a distance of 40 to 50 yards out, or from the trees in the regular windbreak proper, and is composed of a single row of willows. The necessity for a snowbreak gets more apparent as the trees in the windbreak increase in size, holding large snowdrifts, the trees being liable to be broken down or seriously injured in consequence. This danger is being realized by planters, and as a result the increased interest in snowbreaks.

Your obedient servant,

A. P. STEVENSON.

APPENDIX No. 5.

REPORT OF JOHN CALDWELL, TREE PLANTING INSPECTOR.

VIRDEN, July 3, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I beg to submit to you my report for 1906

The territory given to me this year is the same as for 1905, namely, the Canadian Pacific Railway main line from the Manitoba western boundary to Regina, the Kirkella line to Balcarres, and the Pipestone line from Regina back to Manitoba.

Since my last report I have assigned to farmers about a quarter of a million young trees, having found land ready or being prepared for that quantity. The average to each farmer would be about 1,800 trees. I seldom give less than 1,000 to any one man and not often over 3,000. One-half acre planted 4 by 4 feet takes about 1,500 trees, and it is very desirable that all farmers who are out on the open prairies should have

plantations north, east and west of their buildings, not too close but leaving plenty of room for a good sized barn yard. Such a plantation adds greatly to the comfort, value and cheerfulness of farm life. A few years of such work will change the whole face of the country, giving it a more homelike and prosperous appearance.

I find the farmers only too glad to avail themselves of this opportunity of getting plantations, but the inspectors can hardly be too careful in giving advice as they are so liable to make serious mistakes. One man would take 10,000 trees when he has hardly time to care for 3,000; another would plant all around the farm which would not be wise when he has no trees around his buildings; some will plant too close, some too far apart, and some too shallow. A little talk on how to plant is always in order, and how to trim roots if planting with a dibble, which is sometimes the best and quickest way, when planting one-year olds.

One great reason for the many failures in the early tree planting through Manitoba was the lack of proper instructions. There is hardly a farmer living out in the open prairie but intends to plant trees. We have a few beautiful plantations in almost every district. These are examples and an encouragement for the neighbours to do likewise.

I find a failure here and there and some only middling, but fully 75 per cent of the plantations are quite satisfactory, probably 90 per cent of all trees planted so far are growing.

This season so far has given us a heavy rainfall, and while it is good for trees it is also good for weeds, and we should be careful not to give farmers more trees than they can well care for.

The varieties of trees distributed in my district so far have been principally native maple, native ash and cottonwood from North Dakota, with a sprinkling of elm, willow and Russian poplar. The hardwood trees (ash and elm) are of slower growth than the rest, but in the end will be the best and for a plantation to be permanent it is very desirable to have 25 per cent of the trees hardwood. The Russian willow and Petrofsky Russian poplar, are also fast growers and very hardy; and it is good to have a mixture of them in all plantations. The poplars are better sent out as stout cuttings, and the willows would be safer if small cuttings were rooted one year old.

With good windbreaks farmers will be in a far better position to plant all kinds of nursery grown trees, shrubs, small and large fruits. Some large nurseries are being established in the west and these plantations will prove a benefit to them as well as to the whole country. I find every one in the towns as well as in the country speaking very favourably of this government tree planting among the farmers, and the work should certainly be vigorously carried on, especially in the newer districts where settlers are flocking in, often where the prairie is perfectly bare and never a tree to be seen. It is not hard to imagine how anxious these newcomers are for a little shade and shelter and how glad they seem to accept the government aid in the way of tree planting.

I have a good many foreigners on my list this year, and my past experience with them has been very satisfactory. Most of them are from countries where forestry receives a good deal of consideration, and they show quite a desire and love for tree planting.

I am marking quite a lot of names off the list this year as being pretty well supplied. Although it would pay farmers to plant a block of trees for fuel posts, &c., few of them care for more than shelter around their buildings, as they do not wish to spend the time, there being so much other work to do in the way of improvements. No doubt planting for fuel and timber will develop later on, and in the meantime we have probably all we can do to attend to the newer settlers.

I had the pleasure of looking over the forest nursery at Indian Head with Mr. Ross a short time ago, and was delighted with the healthy growth of the plantations. I consider the forest nursery a splendid and well managed institution. Millions of healthy, well grown young trees are growing there at a very small cost.

Your obedient servant,

JOHN CALDWELL.

APPENDIX No. 6.

REPORT OF ANGUS MACKINTOSH, TREE PLANTING INSPECTOR.

HANLEY, SASK., September 7, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour of sending you my third annual report on the tree planting done through the co-operation of the Forestry Branch and the settlers in that part of the Northwest allotted to me for inspection.

At the time of sending you, on the 20th of August, 1905, my last report I had nearly two months' work before me between the head of Last Mountain lake and Eagle creek; round Saskatoon, Rosthern and Osler; and away to the west through that newly opened up country, watered by the North Saskatchewan, from Great Bend to Lloydminster. There are quite a number of thriving shelter belts and small plantations that are a pleasure to inspect now growing in the districts that have Saskatoon, Osler and Rosthern as centres; and even out the length of Eagle creek, a district that at the time of my first visit was a solitude broken only in a few places—tree planters have been successfully at work. Out the Great Bend, Battleford and Lloydminster way also a very promising beginning has been made, and now that the Canadian Northern railway will enable settlers to get trees without having to haul them over the old trails a hundred or more miles, applicants in that quarter are sure to increase.

It is very satisfactory to find that most of the recipients of trees give them every care. Indeed one at times feels surprised that men who are still in the midst of the pressing work of making for themselves homes in a new country should be able to do so well.

Putting off applicants that have not got ground properly prepared for trees has at times to be done, and it is always necessary to give them the reasons why. They think it hard to be put off for twelve months, and it takes some talk to convince them that trees planted on well worked ground, that is, the sod well rotted, and the soil deep-ploughed and well broken up—grow as much in one year as trees on badly prepared ground grow in two, and that keeping the ground cultivated is easier.

My advice is often asked about pruning, especially by those who have sheltered belts so advanced that they need no further soil cultivation. I point out to those inquirers the necessity of keeping the leaf canopy unbroken that the shade may kill the weeds and help to keep the moisture in the soil, and that nature should be allowed to do the pruning.

This season I began inspection work on the 1st of July at Lipton on the Kirkella Railway, working westward to Strassburg; then up the east side of Last mountain, and after that across the country to the Touchwood Hills. A further list of applicants with which I was supplied by Mr. Ross covered the country on each side of the Canadian Pacific Railway from Regina to Swift Current, and also the Prince Albert Branch, and the Canadian Northern Railway from Saskatoon to Lloydminster.

The plantations I have visited are on the whole in a satisfactory state, the failures not exceeding 5 per cent. The desire for trees is spreading greatly and extends into such outlaying settlements as those north of Swift Current, 80 miles from any railway.

The young trees everywhere have come through the winter unscathed and look very vigorous.

In my last report I mentioned the satisfactory growth made by coniferous trees in the neighbourhood of Pense, and my visit this season to the plantations on Mr. Spring Rice's property was one fraught with pleasure. That gentleman's plantation of tamarac is the best I have seen in the Northwest. The trees were planted three years ago, and they now stand from 7 to 8 feet in height. They are full of vigour, of very even growth, and quite overtop the other trees with which the plantation is mixed. Standing on sloping ground facing the north, on soil that is not of great value for agricultural purposes, they promise to become highly remunerative. I may mention that on somewhat different soil and in a different situation the tamarac is making equally good growth at the Forest Nursery Station, Indian Head, affording an excellent object lesson to all who visit that place, so full of interest to lovers of trees.

I have now got the length of Hanley on the Prince Albert branch, and have two months' work before me still.

I am, sir, your obedient servant,

ANGUS MACKINTOSH.

APPENDIX No. 7.

REPORT OF A. H. D. ROSS, M.A., F.M., TREE PLANTING INSPECTOR.

NEEPAWA, MANITOBA, September 14, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—Following your instructions of June 15, 1906, I have inspected 186 of the tree shelter belts already established about the homes of settlers in Manitoba and Saskatchewan by the co-operation of the Forestry Branch of the Department of the Interior, and have examined the land prepared by 89 settlers who have asked for advice and assistance in the matter of growing trees for shelter purposes.

My territory included the plantations, and proposed plantations, that could best be reached by driving from suitable points on the main line of the Canadian Pacific Railway, from Winnipeg to Kirkella ; the Varcoe, Lenore and Miniota branches to the north of the main line, and the Yorkton branch, from Portage la Prairie, Manitoba, to Sheho, Saskatchewan. During the 55 days of actual driving the distance travelled was 2,118 miles, an average of 38·5 miles per day, and the amount paid for livery hire was $222. The average number of plantations inspected each day was only 5, and the average price paid for livery hire was 10·48 cents per mile, or 80 cents for each plantation visited. These facts show how widely scattered the plantations are, but it should be remembered that each one of them is a splendid object lesson on the possibility of growing trees on the plains.

Fourteen of the plantations inspected were started in the spring of 1902, 19 in 1903, 40 in 1904, 49 in 1905, 64 in 1906, and out of the 89 whose land I examined I have recommended 76 for trees to plant in the spring of 1907. The remaining 13 have not suitably prepared the ground for tree growth and have been advised to get it in first class condition for the spring of 1908. Thorough cultivation of the soil before planting and keep its surface frequently stirred for two or three years after planting is the key-note of the success that has been attained in the growth of trees in the prairie provinces. Where they have been properly cared for less than one per cent of them have died. As far as my observations for 1906 go, about 95 per cent of the trees set out since 1902 are alive and fully 85 per cent of them are doing well.

Your obedient servant,

A. H. D. ROSS.

APPENDIX No. 8.

REPORT OF F. W. H. JACOMBE, M.F., TREE PLANTING INSPECTOR.

YELLOW GRASS, SASK., September 8, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I received my appointment as inspector of tree plantations in the Northwest in the spring of the present year, and, as soon as I could arrange to do so, left the Yale Forest School, immediately before the close of the last term of my course, and came west to take up my duties. After some days spent in preliminary work I began my work of inspection at Elm creek, Manitoba, on June 28.

The lines first assigned to me were as follows :—

(1) Elm creek to Souris and west to Antler ; (2) Souris west to Estevan ; (3) Deloraine to Lyleton.

The work of inspecting these three lines was finished on August 24. The great majority of those called on had their trees in good shape. A few cases of failure have occurred through the applicant having undertaken the care of too many trees. Neglect of the trees was more often traceable to the building of new houses, barns, &c. Trees on rented places were seldom or never properly cared for.

The spring of 1906 was throughout southwestern Manitoba favourable to the growth of the seedlings planted, and very few of them have died; three per cent of the whole number planted would, I think, be a liberal estimate. The ash have been especially hardy.

In a number of cases complaint was made of damage by jack rabbits which eat off the tops of the trees in their first winter. The jack rabbits prefer the ash, though they sometimes attack cottonwoods. Maples are seldom, if ever, damaged by them. The changeable weather of last winter and spring resulted in the freezing back of many maples and cottonwoods. These, however, have usually grown up from the root. Insect pests were rare. The vagabond blight of the poplar was found on a number of cottonwoods.

On finishing the above lines I was asisgned (4) The 'Soo line' (from Drinkwater to North Portal) on which I am now engaged.

Along this line the spring and early summer were marked by excessive rains which on heavy soils interfered with the cultivation of the trees, and in one or two instances, in low situations, made it almost impossible to plant. The wet weather has been followed by a long and steady drought which has lasted since early in July to the present time. Growth has consequently not been as good as in more favoured places; though where the trees have been well cultivated it has been good. This section of country is, of course, much more recently settled than most of the parts of Manitoba in which I have been, and there seems to me more temptation in busy times to leave cultivation of the trees to a more convenient season.

In some sections a large proportion of the settlers have come from the western states (mainly from Minnesota, the Dakotas, Iowa and Nebraska), and these seem especially anxious to secure trees, having learned in their former homes the value of trees on the prairie.

Your obedient servant,

F. W. H. JACOMBE.

APPENDIX No. 9.

REPORT OF JAMES LEAMY, CROWN TIMBER AGENT, BRITISH COLUMBIA.

NEW WESTMINSTER, B.C., September 17, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour to submit the following report in connection with fire guarding the timber in the railway belt within the province of British Columbia.

As you are aware, up to the present time we have had an exceedingly dry season, very little rain having fallen. Early in April last, a fire originated in the Cultus Lake district which ran over about four square miles of territory, doing considerable damage to young timber but very little harm to the large timber. This fire started at a time when least expected and made considerable headway before we could get men to work at it to prevent it spreading. However, as soon as we got the men on, they succeeded in checking it and so prevented the fire from spreading. Since April last we have had scarcely any rain and consequently I have been obliged to keep a considerable force of men constantly at work patrolling and fighting fires which have been numerous. I am pleased to be able to report that very little loss of timber has occurred within the railway belt. What fires have occurred have been caused by settlers in the clearing of their lands, by parks from locomotives and in the upper country from lightning, in fact the majority of fires in the Upper Columbia River district can be traced to lightning.

As soon as the danger season is over I will submit a further report, giving details of each and every fire, its location, &c. I am pleased to say that rain began to fall about the sixth of the present month, and I consider the danger from further fires has been minimized considerably, but it will be necessary to watch over the various districts carefully until satisfied that all danger has passed.

In concluding this short report, I wish to add that I am of the opinion that the system of fire guarding established by you and which is carried out in the railway belt of the province of British Columbia under your supervision, has proved to be most successful ; this year we have again succeeded in preventing the loss of valuable timber which was an annual occurrence prior to the inauguration of the system now prevailing.

All of which is respectfully submitted.

I have the honour to be, sir, your obedient servant,

JAMES LEAMY,
Crown Timber Agent.

APPENDIX No. 10.

REPORT OF JOS. E. STAUFFER, FOREST RANGER IN SOUTHERN ALBERTA.

DIDSBURY, ALTA., July 9, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I beg to submit my report regarding forest fire ranging in Alberta, south of the Saskatchewan river, for the year ending June 30, 1906.

During the fall of 1905 we had no fires that did any harm.

The fall of snow during the winter was very light and fires began to run in the woods early in March. The woods were exceedingly dry from the 1st of March up to the 15th of May. There was no rainfall to amount to much during that period.

During the early part of April fires were set out by unknown persons in township 32, ranges 6 and 7, west of the 5th meridian. This fire spread and burnt up the area lying between Red Deer river and James river. It burnt considerable valuable timber on timber berth 253. About the same time fires set out by Indians in township 31, range 7, west of the 5th meridian, burnt over the area lying between the Red Deer river and Fallen Timber creek. This fire, after desperate fighting by all the available men we could get, got beyond control on a very windy day, and burnt about 50 million feet on timber berth 252.

There were also several fires north and south of the Raven river which burnt over a large area, but Fire Ranger Robinson reports that there was only a small quantity of valuable timber destroyed.

I would estimate that between 75 and 90 million feet of timber was burnt by these fires.

West of the 5th meridian to the base of the Foothills there are many small blocks of timber of from 250,000 feet to a million feet, and in the northern part of my district quite a few small timber berths. The settlers are taking up homesteads adjacent to and among these blocks and timber berths, and there is continually a stream of land seekers going into these districts. This makes it very difficult for a ranger to prevent fires being set out, as with the present staff of rangers it is impossible to keep track of travellers through timbered parts. In some cases I know of settlers squatting on timber berths.

I always understood that Indians would never set out fires in the forests, but this year I was convinced that they do; for hunting purposes, in season or out, in the Banff Park and out of it. They set out fires in the spring on their fishing and hunting trips in order to draw deer later for grazing.

Your obedient servant,

JOS. E. STAUFFER,
Forest Ranger.

APPENDIX No. 11.

REPORT OF C. A. WALKINSHAW, FOREST RANGER IN THE TURTLE MOUNTAIN FOREST AND GAME RESERVE.

BOISSEVAIN, June 30, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I beg to submit to you my report on Turtle Mountain Timber reserve for the past year.

Last year was a splendid year for young trees ; as there was lots of moisture and they made great growth. This year is just as good and everything in the reserve looks fine. The month of May was very dry and warm and gave us considerable trouble fighting fires coming from the American side in range 21. There were strips burned in this range, some of them nearly across the township. By hard work we succeeded in stopping the fires before they got into the green timber at the east end of the township. It seemed to me that the settlers along the international boundary on the American side were trying to burn up the reserve. I counted fifteen big fires burning about half a mile across the boundary. Fortunately the wind changed and blew them south ; otherwise all the people in Manitoba could not have saved the reserve. When all danger from the American side was over the settlers along the edge of the reserve in township 2, range 21, started fires four or five at a time that burned over sections 12, 11, 10 and 6, in township 2, and part of section 31 in township 1, range 20. Before we got it under control another fire was started on section 29, township 2, range 20, and burned along the edge of the reserve to section 33, township 1, range 20, where it got into the reserve but did very little damage, except in small strips.

I did my best to find out who set the fires on our side but failed to get evidence to convict any one although I had strong suspicion of some parties who were seen coming from the part where the fires started. I would strongly recommend that no person be allowed in the reserve after the first day of May until the first of November unless they have a permit describing their business in the reserve, and if they do not have a permit give the ranger the power to prosecute for trespass. With the assistance of one man I am building trails where necessary in the reserve. At present we are working in range 20 bridging creeks and low places. I would have been finished in this range before this but for some tremendous rains overflowing and washing away some of our work. Later I hope to do similar work in ranges 19 and 21 which will enable me to patrol the reserve more effectually.

I am, sir, your obedient servant,

C. A. WALKINSHAW,
Forest Ranger.

APPENDIX No. 12.

REPORT OF JOHN RUTHERFORD, FOREST RANGER FOR THE MOOSE MOUNTAIN TIMBER RESERVE.

CARLYLE, September 3, 1906.

E. STEWART, Esq.,
Superintendent of Forestry,
Ottawa.

SIR,—I have the honour to forward you the following report of affairs in Moose Mountain Timber reserve.

The growth of young timber is good and the dry wood is nearly all cleaned up now. I think with the present condition and freedom from fire we will have good success.

I have the honour to be, sir, your obedient servant,

JOHN RUTHERFORD.